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Weed Science

A Plea For Thought

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WEED SCIENCE A Plea for Thought

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WEED Science - A Plea for Thought

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PREFACE

Common wisdom in the research community suggests that defining the problem is half the solution. Evidence of the viability of this perception can be seen in the continuing intense research planning activities of the Experiment Station Committee on Organization and Policy and the Cooperative State Research Service. The recent publication "Research Agenda for the 1990's" is one product of this planning activity which in its conception sought input from a large number of agricultural interest groups, the scientific community and the research administrative community to define the problems that would bring focus to the research agenda for the 1990's.

A high priority research initiative which emerged from this planning effort is the **SAFE AND EFFECTIVE MANAGEMENT OF PESTS**. The research emphasis perceived as appropriate for the future is a great emphasis on non-pesticidal methods of controlling pests. The challenge facing the research planners that attempt to translate this generic conception into specific plans is addressed in Dr. Zimdahl's essay--"Weed Science - A Plea for Thought." Can the weed science research planning community overcome the paralysis of the pesticide paradigm and conceive a weed science research program that addresses both society's perception of safety and the scientific community's perception of risk?

This essay, "Weed Science - A Plea for Thought," has been prepared as a symposium preprint to call attention to some of the assumptions and attitudes operative in both the scientific community and the community of thoughtful critics of the pesticide paradigm. This essay will serve as a cognitive launching pad for a weed science research planning symposium to be held in 1992.

We invite your thoughtful attention to the essay.

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Richard L. Lower, ESCOP subCommittee on Pest Strategies
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March, 1991



Chapter One

The Need for Historical Perspective



Prometheus, the Titan whom Zeus employed to make men out of mud and water, stole fire from the heavens and gave its power to man. With this gift of fire Prometheus fulfilled his destiny to be creative and a courageously original life-giver. Man had the power to become toolmaker, explorer, and food grower. However, Zeus did not appreciate disobedience by a lesser god and punished Prometheus by chaining him to Mt. Caucasus where an eagle came each day to eat out his liver which Zeus renewed each night.

Although Prometheus was punished, the gods schemed further to control man's power. They created Pandora whose name means "all gifted" because each of the gods gave her something. She was endowed with Aphrodite's beauty, Hermes' gift of persuasion, and Apollo's music to entice the heart of man away from full use of fire's power. They also gave Pandora burning curiosity, as well as a box, a gift for the man she would marry. With the box came the warning that it must never be opened. Prometheus (whose name means forethought) mistrusted Zeus and his gifts, but his brother Epimetheus (or afterthought) married the beautiful Pandora, and accepted the box, the gift of gods. One of them, Pandora or Epimetheus, opened the box, and once opened, it could not be closed; thus all that is evil escaped into the world to torment mankind forever--only one gift, hope, remained. How interesting that Prometheus--forward looking, life-giving, creative, courageous, and Pandora--beautiful, enticing and persuasive, but whose fatal curiosity loosed a thousand plagues, are part of the same myth!

For most of the western world's history, we have gloried in our Promethean power--the power of science. It has permitted us to change from toolmakers to developers of sophisticated instruments and machines and from explorers to conquerors. The power of science has changed the developed world's agriculture from subsistence to abundance and even surplus. We quickly learned how to use and benefit from the Promethean gift of fire and power and Pandora was forgotten except as part of an interesting myth. However, for all its wonders and undeniable bene-

fits, science and its associated technology have a disquieting aura of fallibility. Pandora may be a more important part of our inheritance than Prometheus.

Science has given to no one in particular, powers that no one knows enough about.

In the past century, communication speed has probably increased more than 10^{17} times. We have moved from sea-mail and the pony express to nearly instantaneous, worldwide, satellite-aided communication. When Levi Zendt left his Amish heritage and traveled West to Colorado in James Michener's novel "Centennial" his wagon pulled by horses could make about 10 miles per hour on level terrain in good weather. Now we think nothing of moving across the country in a day and spaceships which travel 18,000 miles per hour are hardly front-page news. In World War II a "blockbuster" bomb, containing 20 tons of TNT, was a bomb that could destroy a whole city block. The Hiroshima atomic bomb had the explosive equivalent of 20,000 tons of TNT and now we have a single thermonuclear hydrogen bomb with the explosive equivalent of 25 million tons of TNT. That is more explosive power, in a single bomb, than in all the bombs dropped, by both sides, in World War II. Our ability to destroy has increased over one million times in the last 40 years.

Almost everyone has experienced the benefits of modern antibiotics which started with Alexander Fleming's discover of penicillin in 1929. Modern birth control technology has made life easier for many women and families. In the 1940s my parents worried about infantile paralysis (polio) but I have not worried about its effects on my children, thanks to Dr. Salk and Dr. Sabin. In the last 40 years a whole series of discoveries in molecular biology have revealed the structure of proteins and nucleic acids. We are now on the verge of modifying genetic structure and perhaps even creating new genomes. You may, one day, order designer genes from the Sears catalog.

Modern science is the engine that drives the West's great agricultural productivity. It is the key to power and an important part of the solution to problems we face.

It cannot solve all problems but many cannot be untangled without science.

American agriculture, in particular, has achieved its prominence by substituting scientific knowledge for resources (65). The knowledge has been demonstrated in mechanics, biology, and chemistry and in farmers' managerial skills (65).

Development and use of synthetic fertilizers has been at the heart of advances in agricultural productivity, which could not have occurred without the great improvements in plant productivity contributed by selective plant breeding. The green revolution was, in large measure, a contribution of modern plant breeding. Pesticides also have played a significant role in modifying crop environments by reducing or eliminating insects, diseases and weeds.

Weed science illustrates well the modern dilemma of dependence on science and the untoward effects of that science. It is the role of herbicides in selective weed control that will be dealt with herein. I will explore some aspects of the history of weed control and weed science (which are not synonyms), and some ensuing, perhaps inevitable, problems from their widespread use while reflecting on the future of weed science and pesticide use in general.

Historical Reflection

Technologists do not like historical reflections, especially if they are critical of what is viewed as progress. Technologists seek results and progress. In the technological realm, it is the goal and not necessarily the route to achievement that is important (42). The computer at which I am typing is a good example. It is only three years old and already an antique. It still works and does all I want it to do, but new ones do much more.

Our lives are increasingly ordered by these advances. Not too long ago, one could actually conduct business without worrying whether the computers were "up" or "down." People did things without the aid of these modern technological marvels. Few technologists ask if their achievements are innately desirable or if they will have desirable social conse-



quences. It seems that technological progress is the end, the achievement, and that it is accepted almost without question. The technological challenge is to progress, to grow, to get bigger. In the same view, weed scientists have not been pressed to explore their science's progress or to probe the consequences of their achievements.

Weed scientists, and other pest control scientists, point with pride to their achievements. We can create disease- and insect-free (or nearly free) crops raised in a weed-free environment. These crops yield more and are purported to be more profitable for growers. They are also proclaimed to be more healthy, or at least not unhealthy, for consumers.

Those in pest control have been charged with solving a technical problem created by pests which reduce crop yield and lower quality. The charge has been to reduce pest incidence. The charge has not been to reflect on means, but to accomplish the goal. Knusli (42) contrasts scientists in pest control with a bridge building engineer who, one day, will stand by the construction "tested, safe, ready to use, with no question left open." The engineer moves on to the next, presumably better, project which will benefit from cumulative experience. The last project was complete and final. Knusli (42) goes on to point out that the community of natural scientists cannot dream of reaching a point where a project is complete and final in and of itself. Weed scientists as part of the larger community of natural scientists also cannot dream of reaching a point where their science is complete and final. Natural scientists are building an expanding, deepening picture of nature that will never be complete. We build an evolving view of the natural world. It is an image from a particular point of view and place in time, not the final answer.

Most biologists accede to this view. However, in some narrow sectors of biology, I think especially in weed control, scientists may not operate from this broader biological perspective. We know weed control is evolving but we have been constrained in evolution because we have adopted a single solution to the

problem; the desirable goal of weed control too frequently has been hitched to the technological achievement of herbicides.

What is a Weed

Weeds are ubiquitous, common, and bothersome plants that have been described in terms of their habitat, their behavior, their undesirability, and their virtue or lack thereof. However, not all agree on what a weed is or which plants are weeds. For example:

"A plant out of place or growing where it is not desired."

Blatchley 1912 (14)

"Any plant whose virtues have not been discovered."

Emerson 191 (27)

"Any plant other than the crop."

Brenchley 1920 (17)

"A plant not wanted and therefore to be destroyed."

Bailey 1941 (9)

"Those plants with harmful or objectionable habits or characteristics which grow where they are not wanted, usually in places where it is desired something else should grow."

Muenscher 1960 (58)

"A very unsightly plant with wild growth, often found in land that has been cultivated."

Thomas 1956 (73)

"Weeds are pioneers of secondary succession, of which the arable field is a special case."

Bunting 1960 (20)

"A plant is a weed if, in any specified geographical area, its populations grow entirely or predominantly in situations disturbed by man."

Baker 1965 (10)

"A herbaceous plant not valued for use or beauty, growing wild and rank, and regarded as cumbering the ground or hindering the growth of superior vegetation."

Oxford English Dictionary (49)

"A weed is a plant that originated in a natural environment and, in response to imposed or natural environments, evolved, and continues to do so, as an interfering associate with our crops and activities."

Aldrich 1984 (2)

These definitions range from the poetic descriptions of Emerson to the didactic terms of Baker, Bunting, and Aldrich and the agronomic, control-oriented of Blatchley, Brenchley, Muenscher, and Bailey. The Weed Science Society of America (5) defines a weed as "any plant that is objectionable or interferes with the activities or welfare of man." Many of the definitions are accepted by practitioners of weed control who rarely ask how close to the truth they are.

The Role of Definitions

It is important to note that man is the focus of most definitions. It is we who say that a plant, at a certain time and place, is objectionable or interferes with our activities. It often does not matter that at another time and place it could be desirable or at least not objectionable.

These definitions create a view of nature that is common, if not ubiquitous among weed scientists (and perhaps among most practitioners of pest control). The definitions imply--once a weed, always a weed. There is no presumption of innocence. Only Aldrich (2) offers a definition that provides, as he puts it, "both an origin and continuing change perspective." He says that "recognizing that weeds are part of a dynamic, not static, ecosystem helps us to expand our thinking on how best to prevent losses from them." His definition moves away from those that regard weeds as enemies to be controlled. It is an ecological definition that regards weeds as plants with particular, perhaps unique, characteristics and adaptations that enable them to survive and prosper in disturbed environments.

Although all do not agree on what a weed is, most know they are not desirable. Many even recognize the human role in creating the negative image weeds endure. Often it is a richly deserved image because weeds can be detrimental and must be controlled, but is this always true? Is their lack of virtue more a func-



tion of the image created by our definitions than an absolute fact of nature?

Definitions shape our lives and relationships with other things. Yet another frequent definition of weeds says they often occur in waste places. Weed scientists have heard and used this definition for years without questioning the term “waste place.” We assume it is a place where crops are not grown and plants grow wild and cumber the ground and where it would be good if something else would grow—perhaps something pretty, or at least not ugly. The fact that we accept that weeds occur in waste places creates an attitude toward them and all with which they are associated.

Definitions are powerful creators of images and meaning and we cannot escape them through pleas of objectivity or freedom from values. Capra (21) reminds us that “patterns scientists observe in nature are intimately connected with the patterns in their minds, with their concepts, thoughts, and values.” The research weed scientists do depends on the larger paradigm (of which definitions are an integral part) which shapes and directs the choice of research problems. It will never be value free.

The historian Lynn White (80) thinks we are unquestionably inheritors of the Baconian creed that scientific knowledge leads to technological power over nature and that power is good. Most weed scientists subscribe to the Baconian creed without thinking about it. Modern, successful science and technology are Western and weed science, especially as embodied in herbicides, is part and parcel of Western modernity. White (80) suggests that we have moved from man-as-part-of-nature to man-over-against nature. Man and nature have become separate. Man is master now, and it was meant to be so. Man’s power gives him dominion and he subdues nature even though he may be striving to obtain goals that are ecologically unsound and unsustainable. Nature and natural things are judged by what they can do for man, not by any value judgment about intrinsic natural patterns that control us and are affected by our actions. The basic character of modern man includes an endless

pursuit of things, exploitation of nature and other men and despoliation of nature. Thus, we are alienated from nature and willingly accept definitions which create attitudes that make some things undesirable because they do not fit our immediate goals. White (80) doubts that applying more science and more technology to problems created by science and technology will avoid a disastrous ecologic backlash. He wants us to rethink the Christian axiom that nature has no reason for existence except to serve man.

Black (13) agrees with White that there is an ecological crisis but sees a different cause. Black thinks our ecological crisis does not stem from our Judaeo-Christian heritage, as White does, but rather from a fundamental uncertainty about the past and future of man. Such doubts and the questions they create are often explored in myths. Every individual must answer the eternal questions addressed by some myths and religion: who am I, what is the meaning of my life and of life, and what is the purpose of existence. Whether we confront, ignore, or remain unaware of these questions, they cannot be rejected as irrelevant. We, those who have preceded us, and those who follow will struggle with them.

Black (13) concludes “that almost the only course open to western man is based on a vision of mankind stretched out along the dimension of time. By redefining mankind in terms of the whole of humanity dead, living, or as yet unborn, we may perhaps be able to assess what we do in terms of the good of mankind, regardless of the position of the individual along the time axis of the world.” Black sounds much like Heilbroner (37) who argued for the “transcendent importance of posterity” to each individual.

Wendell Berry (12) disagrees with White’s (80) interpretation of Genesis and the Christian message but agrees with White’s hypothesis that we regarded ourselves especially in agriculture, to be in a state of war with nature. Berry suggests we must not use the world as if we created it ourselves. Land and earth exist independent of people, and their existence is not dependent on human purpose. White (80) wants us to rethink our reason for being,

and Black (13) challenges us to include a future dimension to life while redefining ourselves in relation to others. Berry fundamentally agrees but sees that the most necessary thing in agriculture is “not to invent new technologies or methods, not to achieve breakthroughs, but to determine what tools and methods are appropriate to specific people, places, and needs, and to apply them correctly.”

Marx (53) cites White (80) and agrees that Christianity has given the West an “aggressive man-centered” environmental attitude—an attitude that assumes that only when man achieves the ultimate, hoped for, unity with God can we transcend nature and achieve dominance and adjust or force nature to our ends which, of course, are what God intended from the beginning. Marx (53) suggests that even conservationists see a world that exists apart from and for the benefit of mankind. The philosophical root of Marx’s ecological ideal is the secular idea that man is “wholly and ineluctably” embedded in the natural world.

Certainly it is the view of many that our agricultural-ecological problem is an attempt to transcend nature and it is rooted in the West’s profit-oriented, business-dominated society (53). This results in violation of ecological standards for short-term gain but no obvious (short-term) cost. Marx (53) cites the omnipresent expansionary or frontier ethos of the U.S. which “like a powerful, ideological hormone, stimulates reckless, uncontrolled growth of each cell in the social organism.” For Marx, our basic confrontation is the extreme imbalance between each citizen’s desire to satisfy the growing total of individual wants and the limited capacity of a closed ecosystem to give everyone what they want. Some even question if the 6.2 billion people projected to be on earth in 2000 will be able to have what they need, much less what they may want.

Is it possible that simple definitions of simple things can lead to trouble and misdirect our power? I suggest that it is and that weed science is an area of study that has lost its way because of wholesale acceptance of unexamined definitions and technologies. We need to study our his-



tory, not assume it, and then evaluate it as a guide to the future.

The History of Weed Science

Weed Scientists are not historians, but if weed scientists think about the history of their work, they probably assume it is similar to the history of similar groups. I suggest that this assumption of similarity is an error. I do not purport to be an historian of weed science, but after nearly 25 years experience in the field, I can comment as an internal historian--although colleagues who have read this far may think I have lost my way.

Not many weed scientists have investigated the history of weed science. The historical accounts which have been written are accurate, but are almost exclusively a history of chemical weed control (23,68,70,75,76,84).

Upchurch (76) says that "one approach to studying the beginnings of weed control is to examine the appearance of various herbicides." He is correct but it is interesting that his approach is the one commonly taken by writers.

Many writers cite the early work of Bolley in North Dakota (15), and the nearly concurrent work of Frenchmen Bonnet, Martin and Duclos and Germany's Schultz (cited in 24). Each of these men used solutions of copper salts for selective weed control in small grains; later iron sulphate and sulfuric acid were used.

Succeeding work in Europe observed the selective herbicidal effects of metallic salt solutions or acids in cereal crops. Names encountered frequently include Rabate in France (63), Morettini in Italy (56), and Korsmo in Norway (44). More recent historical accounts almost always cite the synthesis of 2,4-D by Pokorny in 1941 (cited in 41), the discovery of its growth regulating properties (85) and the first reports of its herbicidal activity in the field (34,35,52). Work was progressing in England at the same time on herbicidal uses of MCPA, a close relative of 2,4-D (66). The first paper on a non-phenoxy acid derivative useful as a herbicide was by Bucha and Todd (18) who reported the herbicidal properties of

monuron the first, of many, phenyl urea herbicides.

When a weed science textbook or paper discusses history, it notes that weeds have been with us since settled agriculture began. Smith and Secoy (70) state that harmful effects of weeds were known to early historic man and cite the evidence of hoes and grubbing implements that have been found. They also found that nearly all books from Theophrastus to modern times have mentioned weeds and their detrimental effects. It is not hard to find examples of man's battle with weeds. The thistles and thorns of Genesis (3:17-18) and the parables of the sower (Matt. 13:18-23) and the tares (Matt. 13:25-30) are among the earliest references.

In many parts of the world farmers are people with hoes, and weeds are part of the burden of agriculture. Control, if achieved, is an incidental part of production. Control has progressed from hand removal and primitive hand tools to animal powered implements. Weed science and planned weed control began following World War II with the discovery of the herbicidal properties of 2,4-D. Thus, this new science of weeds is and has been from its inception, a pragmatic science. We are problem solvers.

There were herbicides before 2,4-D but none were as cheap, as effective, or as selective. Crafts (23) traces the history of herbicide development from the early workers cited above to the 1920's discovery of the bindweed control potential of a dilute solution of sodium arsenite and its apparent translocation in plants. In Colorado, workers applied carbon bisulfide as a soil fumigant to control Phylloxera, the root-borne disease of grapes. They noted bindweed was killed and soil fumigation with carbon disulfide came into widespread use. It is reported that over 300,000 acres were treated in one year in Idaho.

Crafts (23) also outlines the early work on sodium chlorate, sodium arsenite and sodium dinitroresylate. These true and interesting accounts confirm my earlier point that the history of weed control has been presented and is understood as the

history of chemical control. Although other methods were widely used. The need for weed control has long been widely acknowledged, but introduction of the ability to selectively control weeds provided the stimulus for development of what we now call weed science.

Timmons (75) noted that State weed laws were first enacted between 1721 and 1766, but they were not weed laws as we now know them. The laws were directed at control of plant diseases spread by weeds which often serve as alternate hosts. There were only a few Extension Service publications on any aspect of weeds between 1860 and 1900 (75). Few others were added until the 1950s. Weed control was a minor part of agronomy, botany, horticulture and plant physiology until the 1950s (75). The journal *Weeds* (now *Weed Science*) was not founded until 1951 and the Weed Science Society of America was founded in 1956. The primary European weed journal, *Weed Research*, was founded in 1961.

Throughout our brief history weed science has been suffused with what Veblen called exoteric knowledge (33). This is knowledge which has negligible academic prestige but is very useful. Ours is a science that is dominated by pragmatism. No one has or is likely to accuse weed scientists of generating only esoteric knowledge which Veblen said has great academic prestige but is without economic or industrial effect.

The History of Other Plant Protection Disciplines

The history of weed science is brief compared to that of entomology and plant pathology. The latter two began as applied sciences, and both retain a large amount of applied work. They differ from weed science in that each has a causal organism that can be isolated and identified. The effect of the organism in plant pathology is called a disease, and insects cause growth malformations or reduced growth. The cause is usually apparent when a disease or insect is present. Weeds are also abundantly obvious, but their yield reducing effect on the crop is not equally obvious. They are often just there and the crop seems all right because weeds don't cause the obvious effects



that other organisms cause. Weeds don't eat things as insects often do or immediately cause wilt or malformations as diseases often do.

All three plant protection disciplines trace their origin to the Bible and cite it as evidence of ancient awareness of problems caused by the pests of most importance to them. Christian literature is replete with examples of insect scourges, and blast and mildews are common in the Old Testament. The first to write about plant diseases of trees, cereals and legumes was Theophrastus (370-286 BC) (1). His approach was observational and speculative rather than experimental and little more was added to our knowledge of plant pathology for the next 2000 years (1).

In the 16th century, botanists were intent on naming and describing plants rather than investigating how they grew and developed. The dogma of constancy of species led to the apparently logical assumption that fungi arose by spontaneous generation. Farmers of that age accepted disease as an inevitable concomitant of crop growth just as unfavorable soil and climate were conditions agriculture had to accept. From the 16th well into the 18th century many prominent botanists were skeptical of spontaneous generation, but the theory held (1).

Discovery of the compound microscope in the 17th century made new observations possible and began a new phase of plant pathology. Working with a microscope in 1675, Anton van Leeuwenhoek discovered bacteria, but his discovery did not influence spontaneous generation. Fungi were a result not a cause of disease (1).

In the 19th century the influence of human pathology in interpretation of plant disease was strong. A comprehensive paper on fungi was written by the German botanist Anton de Bary (1831-1888) when he was 22 years old and he thereby entered the controversy about the relation of fungi to plant disease. He opposed spontaneous generation and advocated fungi as plant parasites and causes, not symptoms, of plant disease.

Science, in the 1800s, was shifting from a philosophical approach to experimentation and inductive reasoning. However, throughout the 18th century, the prevailing concept remained that lower organisms arose *de novo* from inanimate substrates. Spallanzani, at the end of the century, and Tyndall and Pasteur several years later, finally disproved spontaneous generation (72). Even after 1860, when Louis Pasteur showed that microorganisms arose from pre-existing organisms and that fermentation was a biological phenomenon rather than a purely chemical one, spontaneous generation persisted. Tradition dies hard, even in objective science. Pasteur's work was not widely accepted and the germ theory of disease for man and animals was not established in 1860. de Bary's continued work provided a foundation for the germ theory of plant disease, and he is regarded as the father of modern plant pathology.

Plant pathology texts first appeared in Europe after the mid-1850s and took a taxonomic approach (72). T. J. Burrill of the University of Illinois (78) was the first to relate a bacterium to the cause of fire blight of pears. Leadership in the study of bacterial diseases was led by American scientists in the latter part of the 19th century and Burrill's work was greeted with skepticism by Europeans who regarded themselves as leaders.

The U.S. Dept. of Agriculture was founded in 1862 and the Division of Botany was organized in 1885. The section on mycology was begun in 1886 and its name was changed to the section of vegetable pathology in 1887 and to the Division of Vegetable Pathology in 1891 and finally to the Bureau of Plant Industry in 1901. The Federal government's Hatch act, which established State land grant agricultural experiment stations, was passed in 1887 and by 1890, plant disease studies had begun in many states. In fact, H. L. Bolley (15), who is cited by weed scientists as a founder of selective chemical sprays for weeds was working as a plant pathologist in the North Dakota agricultural experiment station.

Plant pathology began to emerge as a discipline toward the end of the 19th

century and was well established in the U.S. and Europe by the beginning of the 20th century. The emerging discipline was characterized by studies of taxonomy and description of diseases and their causal agents (112). Early work did not center on disease control. It is not even known if control was a goal of the pathologist.

When potato blight swept across Europe in the 1840s and the Irish potato famine occurred, its cause was not agreed upon. Only slowly was it accepted that mold associated with affected potatoes was the cause and not the result of disease (72). It was de Bary who finally established that *Phytophthora infestans* was the causal agent of potato blight. However, it is important to note that the research was directed at finding the cause not a cure for an undefined problem.

Because man has always been more concerned with human and animal health than plant health and because insect-vectored diseases became the province of entomology, plant pathology was slow to develop. Human and animal pathology dealt with diseases whose importance was accepted, but plant pathology has never had the comprehensive scope that medical or veterinary science has enjoyed.

We know that fungicides developed slowly through empirical observation before the germ theory of disease was well established. Sulphur was used for many years as a fungicide. A landmark was its introduction in 1802 by William Forsyth (1737-1804), who, as gardener to King George III, used lime sulphur for control of mildew on fruit trees (72). Toxicity of copper to fungi had been noted by Prevost in 1807.

Tarr (72) regards the turning point in use of chemicals for plant disease control as the introduction by P. M. A. Millardet (1838-1902) in about 1885 of Bordeaux mixture (copper sulphate, lime, and water) in France for control of downy mildew (*Plasmopara viticola*) of grapes (*Vitis vinifera*). It is also cited as one of the starting points for herbicides because a good observer noted that it turned leaves of some species of mustard black. It thus



acted as a selective herbicide and the event is often cited as the origin of work on herbicidal properties of metallic salts. Organic fungicides began appearing in 1913 when chlorophenol of mercury was used to treat wheat seed for control of bunt, or stinking smut (*Tilletia caries* or *T. foetida*). It was followed by red copper oxide and zinc oxide.

Entomology's history is similar to that of plant pathology. The science developed early and Richard (64) provides a continuous curve showing the life history of 56 entomologists from 1700 to 1950. Much development occurred in China in the 15th and 16th centuries and even earlier (43). But China was an inward looking society with no firm external linkages, and little development occurred beyond early knowledge. The basic character of Chinese scientific philosophy was organismic or holistic, not experimental or analytical. The Chinese saw the world as a pattern of relationships which were to be studied and understood.

In the West, zoology did not exist until Aristotle, and the term "insect" is not found in Biblical Hebrew or other languages of the era (36), but we know that people were not ignorant of insects. Entomology was a systematized and descriptive science in the West from 1700 to the early 1800s. The entomologist's job was to describe and understand insects, their life cycles, hosts, and the damage they did. It was not their primary task to control or devise control programs for insects. The first part of the 19th century saw formation of the most important European entomological societies: France, 1832; UK, 1833; Germany and Holland, 1857; and the Pennsylvania society in the U.S. in 1842 (71).

An Historical Conclusion

Weed science cannot claim the historical lineage that either of the other two major plant protection disciplines can. Although weeds have been around as long as insects and plant diseases, they have not been studied as long. The major actors in the history of weed science all completed their education and developed their careers in the 20th century. Included among them are six major figures:

Wilfred W. Robbins was born in Mendon, Ohio May 11, 1884 (died 1952). He received his Bachelor's and Master's degrees from the University of Colorado and a Ph.D. in Botany from the University of Chicago in 1917. The early part of his career was spent as an instructor in botany and forestry and as a botanist in the agricultural experiment station at Colorado Agricultural College, Fort Collins. He moved to the University of California at Davis in 1922 where he was chairman of the Botany division of the College of Agriculture for 29 years. There he began a program on weed control and developed the first classroom instruction about weeds (24). He authored one of the first textbooks on weed control and was instrumental in establishing the first U.S. weed society--The Western Weed Control Conference in 1938.

James W. Zahmley (1884-1975) was born near Dwight, Kansas, received Bachelor's and Master's degrees from Kansas State University, and spent his entire career in Kansas. He joined the agronomy faculty at Kansas State University in 1915 where he pioneered chemical weed control investigations. He is credited with discovering the use of sodium chlorate for control of field bindweed (*Convolvulus arvensis*) and Russian knapweed (*Salsola iberica*) and was involved with early experiments on the herbicidal potential of sodium trichloroacetate for control of perennial grasses. He was a charter member of the North Central Weed Control Conference.

Many of those now retiring from active weed science careers received their education under the guidance of Charles J. Willard, Professor of agronomy at the Ohio State University and a founder of the Weed Science Society of America. Willard was born in Manhattan, Kansas in 1889 (died 1974) and received his education at Kansas State, the University of Illinois and Ohio State where he remained on the faculty for 42 years. He began the weed control program at Ohio state with studies of chemical control in 1927. He served as major professor for the graduate program of many men who went on to build weed science after World War II.

F. L. "Tim" Timmons was born in Little

River, Kansas in 1905 and received a Bachelor's and Master's from Kansas State University. His professional career was spent in the west and included work in Kansas, Utah, and Wyoming. When he retired, he was recognized as an expert on range land weed control and weed control for aquatic systems.

Erhardt P. "Dutch" Sylvester (1906-1975) was Professor of Botany and Plant Pathology at Iowa State University. For those who knew him, he remains the epitome of the extension weed specialist which he was for 30 years. His contributions derived from his ability to teach weed control to farmers where questions come from experience and need and answers are demanded immediately not in the next day's lecture. Dutch was one of the first to receive a sample of the "magic" herbicide 2,4-D in 1945. He had been preaching the importance of weed control through tillage, clean seed, and good farming practices for many years and with 2,4-D he had a tool to accomplish selective weed control in corn, Iowa's major crop. He developed weed control with herbicides in Iowa, and his program became a model for much of the corn belt.

Another pioneer in weed science was Kenneth P. Buchholtz (1915-1969) who received his undergraduate degree from Washington State College in 1938. He went on to receive a Master's of Science and doctorate from the University of Wisconsin where he remained on the faculty in Agronomy and began the program in weed science. He was a pioneer in weed science and his career paralleled the development and use of selective herbicides. Many of today's active weed scientists received their education in his program at Wisconsin.

Finally, one must include Alden S. Crafts (1897-1990), a Colorado native who spent his professional career at the University of California at Davis. He began as a colleague of W. W. Robbins and built on the foundation Robbins had laid for weed work in California. He received his doctorate in plant physiology from California and did much of the pioneering work on mode-of-action of herbicides and laid the basis for modern studies through his



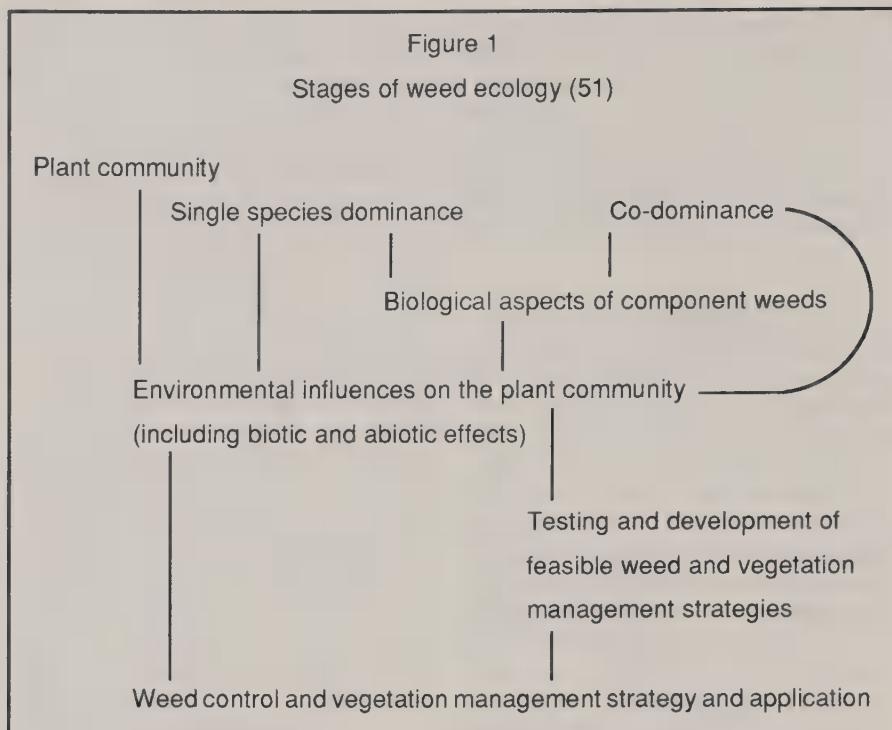
work with phloem structure and function, water relations of plant cells and autoradiography.

The point to be drawn from these brief biographies is that these were all men who completed their education and developed their careers in the 20th century. They began weed science but were not educated as weed scientists because there were no weed scientists who preceded them. They founded a modern science and helped develop a scientific society (the Weed Science Society of America) that now has over 2000 members.

One mark of a mature profession is awareness and understanding of its own history (81). When we know our history then, and only then, can we judge what it means and who we are. History cannot be assumed any more than the results of an experiment can. The history of weed science is different from that of other major plant protection disciplines, and I suggest that weed scientists have been shaped by that history and are not aware of its influence.

As we have seen, the disciplines of entomology and plant pathology began before their practitioners had the ability to control causal organisms. Early scientists studied the causal organism, its life cycle and how it interacted with a host. It was their only choice because effective control was out of the question. My hypothesis is that weed science missed this foundation-forming phase so prominent in the history of other plant protection disciplines. Pre-World War II weed scientists were few in number and control dominated their thinking, even though their ability to control was limited. During their formative years other plant protection disciplines were compelled to develop an understanding of the organisms that they can now control. It must be pointed out that all plant protection disciplines were equally eager to join the pesticide parade after World War II.

Weed science never went through this phase because those who began to try to solve weed problems were so closely followed by others to whom technology had provided the means of control when herbicides were developed after World



War II. Weed science really began to develop after World War II when the ability to control was at hand. These scientists did not need to develop understanding of weed biology or ecology. Their task was to figure out how to use herbicides to kill weeds selectively in crops. That was a demanding task and it remains a difficult job. Great successes have been achieved and much remains to be done to perfect chemical technology. However, much of it can be done without complete, and often with only limited understanding of the weed to be controlled.

Weed science and, in large measure, other pest control disciplines, are now chemically-based, control-oriented, scientific endeavors that often do not rely on understanding of the organism's habits or habitat prior to control attempts. When a new weed appears many weed scientists look for an herbicide or ask what new one is coming along to solve the problem. Other questions about what caused the problem or alternative control techniques do not arise as frequently. We largely ignore the upper half of Figure 1 and concentrate a great deal of successful effort and the time of talented people on the final stage. Moreover, we distort vegetation man-

agement strategies by emphasizing herbicides often to the neglect or exclusion of other techniques.

Within the last decade, weed science has been confronted with several serious challenges including increasing resistance of weeds to herbicides, questions about environmental effects, problems concerning human and mammalian safety, emergence of new weed problems, and increasing regulatory restraints on herbicide development. These challenges have drawn a creative response and a perceptible shift from strict weed control to the developing concept of weed management.

Weed management moves away from strict reliance on control of existing problems and gives greater emphasis to prevention of seed and vegetative propagule production, reduction of weed emergence in a crop, and minimization of competition during a crop's life (2). Weed management emphasizes integration of techniques to manage or anticipate problems before they occur rather than solving them after they are present. Weed management will not eliminate the need for control nor does it advocate that today's best techniques be abandoned in favor of



a return to some pre-existing, pristine kind of agriculture where a mythical balance of nature was preserved. It can maximize crop production where appropriate and optimize grower profit by integrating preventive techniques, scientific knowledge, and managerial talent. We need additional information in all of these areas but the weed scientists task is to increase knowledge of weed biology and ecology so we understand "weediness" and use appropriate controls rather than prophylactic measures that often result in amazing short-run solutions but may worsen long-term problems.

However, we still practice an agriculture and a weed science that have great (sometimes complete) reliance on herbicides for weed control. Berry (12) and

White (80) have argued that this kind of reliance is related to the way each of us views the world--our definitions--and doesn't examine our history. The time has come to rethink our creed. We think we can solve the problems science and technology have created by applying more of the same kind of science and technology because it appears to have worked so far. But, we must consider if it has and will continue to work.

Any science advances not by authenticating everyday experience but by grasping paradox and adventuring into the unknown (16). Weed scientists believe, with a great deal of supporting evidence, that their science has contributed to increasing the world's food supply and reducing the human drudgery of weed-

ing--one of humanity's most onerous and time consuming tasks. But we must face the paradox that reliance on one major means of achieving a desirable end may be counter-productive. We must not abandon what is known, but must continually examine this body of knowledge and its basic precepts and change them when appropriate.

"Do you see any clue?
You have furnished me with seven but of course I must test them before I can pronounce upon their value.
You suspect someone?
I suspect myself.
What!
Of coming to conclusions too rapidly."
(26)



Chapter Two

Pesticides and Value Questions¹

¹Adapted with permission from Bulletin of the Entomological Society of America. c. 1972. Entomological Society of America. See reference 82.



Unexamined, rapid conclusions about anything can be serious errors of judgment, and actions based on them may lead to unanticipated and perhaps undesirable consequences. Pesticide technology has not lacked challenges to conclusions about its role and value. These often have been met by pleas for scientific objectivity and dismissal of allegations as emotionally laden and lacking in understanding of the necessity of high agricultural production, pesticide's role in maintaining production, and the extensive safety evaluation mandated before a pesticide ever reaches the United States market. While not without foundation, these pleas do not allow careful consideration of other arguments and points of view and their logical conclusions. I first encountered the problem of reasoning with opposing points of view in the late 1960s and early 70s when the still continuing 2,4,5-T controversy arose. My thoughts were clarified as I struggled with the inevitable value questions (82). They are reproduced in a slightly modified form in the following material.

"Once upon a time all life seemed to be in harmony with its surroundings. Once upon a time we lived in an orderly world in which change occurred so benevolently it was called progress. There was a place and a time for everything. Six days for work and one for being told the meaning of work. The professor and pastor spoke without hesitation. Dad and Mom told us what good boys and girls did (or mostly didn't) do. The newspaper told it like it was. Uncle Sam could be trusted to make the world safe for democracy. And filling in all the cracks between constituted authorities were reason and common sense." (40)

Then something happened. Something in the pesticide industry that questioned established reason and common sense. The still nagging problem existed that the ultimate effects, if any exist, of long-term low-level exposure to pesticides have not been well enough explained to answer some fundamental value questions. A willingness to ask more difficult technical questions about pesticides, the answers to which were not even measurable a few years ago, and most embarrassing, they were questions we had not

even thought of asking.

We are now challenged for answers about long-term induction of cancer or birth defects, alteration of genes, and interaction with other chemicals. Over the last 40 years, the emphasis in public and environmental health has changed from microbiological to microchemical. Agricultural scientists who knew they were helping to produce more food to feed a hungry world and control insect, disease and weed problems were not ready for the criticism heaped on them for pursuing such a universally acceptable goal.

In attempting to sort out my thoughts on the questions raised about chlorinated hydrocarbons, 2,4,5-T and organophosphate insecticides, I developed an awareness of a level of questioning that had gained public credibility. Although it was not entirely in harmony with my own, I think it is important.

The Value Issue

There is a general agreement among men that all ends or goals should be good. In a value question, problems arise because men do not agree on what is good or what is true. Men disagree concerning use of pesticides as a means to achieve the desirable goals of food production and improved public health. Ends may be analyzed to determine their value. But we who work with pesticides are compelled to analyze them as means to an end and to determine their compatibility. We must recognize that ends pre-exist in means. Pesticides contain only natural ends and not the ends predicted by ardent advocates or determined opponents of their use.

As a seeker of truth concerning untoward effects of these pesticides, I faced the extremely difficult task of penetrating the fog of claims and counterclaims made by strong advocates on the issue. All proclaimed lofty ends. None of us propose to demonstrate the evils which will ensue if we follow our particular right way. No salesman who hopes to sell in volume deliberately sets out to show how use of his product will be detrimental. We who work with pesticides are salesmen for the technological utility of pesticides.

None of us deny the efficacy or utility of many pesticides. These are well defined and accepted, even by most critics. However, it does little good to only point out the advantages. We all acknowledge them and continually remind ourselves of them, thereby strengthening our convictions. Such mental exercises become superficial and may ignore the basic value question raised by use of pesticides which may impair human health. Value questions are being raised by many responsible people who do not a priori question the need for pesticides as tools of modern agriculture but who are concerned about their use and long-term effects.

Available evidence indicates that present levels of pesticide residues in our food and environment do not produce adverse effects on our health. This is heard commonly. The key words are "available evidence." One issue of concern in the late 1960s and early 1970s that is still in the news is the use of the herbicide 2,4,5-T. It was used for broadleaf weed and brush control and was used extensively in Vietnam.

Studies initiated by the National Cancer Institute in 1964 pointed to 2,4,5-T as a possible teratogen. This was new knowledge concerned with the health and welfare of man. Without exploring the many ramifications of the issue and without judging 2,4,5-T, I shall relate some of the available evidence.

The Dow Chemical Company found no increase in the incidence of birth defects in rats fed 2,4,5-T, containing less than 100 ppm 1,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), a known teratogen, at 1.0 to 24 mg/kg of body weight per day. The National Institute of Environmental Health Sciences, in a series of experiments with mice and 2,4,5-T, containing 1.0 or 0.5 ppm dioxin, and fed at 50 to 150 mg/kg body weight per day, found increasing birth defects and fetal toxicity in mice from 2,4,5-T in the purest form available. Renal defects and excess fetal mortality were observed in rats.

The U.S. Food and Drug Administration, using 2,4,5-T at 40 to 100 mg/kg body weight with several levels of TCDD found



increased embryotoxicity and gastric or intestinal hemorrhages in pregnant hamsters. Birth defects consisted chiefly of poor head fusion and absence of eyelids, but were few in number.

Analysis of the data shows that if one chooses the proper test animal (mice) and a high dosage administered by gavage, teratogenic effects can be shown. The relationship between these data and the likelihood of teratogenicity in the "real world" are not clear, and it is on this point that the value question hinges in the case of 2,4,5-T.

The specter that mandates serious consideration and lends validity to the value question is that cast by thalidomide. The lowest effective human teratogenic dose is 0.5 mg/Kg body weight per day. Corresponding values for the mouse, rat, dog, and hamster are 30, 50, 100, and 350 mg/kg body weight per day, respectively. Thus, humans are 60 times more sensitive than mice, 100 times more sensitive than rats, 200 times more sensitive than dogs, and 700 times more sensitive than hamsters.

The Response

The scientific community, the regulatory agencies, the chemical industry, and the public have raised their standards concerning safety of pesticides and other synthetic chemicals with known environmental exposure. Legislative machinery was unavailable for definitive action on teratogens, but action was taken and the questions will arise again. Dr. L. Dubridge (former science advisor to the President) commended the evolution of thinking about health but raised the question of where the end point may be. It is the nature of science that as more research is performed, more new questions arise. He proposed that decisions will always have to be made on incomplete information, and he hoped the judgmental structure and the judged will be sufficiently sophisticated and flexible to accept the knowledge available and to permit changes when new knowledge accrues.

The Mrak Commission commented that "the provision of food and fiber and good health must be weighed by each country

against potential or even actual hazards to health from pesticides. Protection of human health involves a system of priorities which are necessarily different from place to place." Those who work with pesticides base many arguments for their continued use on the premise that pesticides are necessary for production of food and fiber. In general this is a valid assumption, but like most generalizations it is weakened or fails completely in specific situations. The argument often ranks the value of technology in food production ahead of the value of human health.

Under what conditions, would we say that there is any pesticide is so necessary that any risk of one of these effects is acceptable? My family would have to be in more than highly theoretical danger of starving before I would allow any risk. We cannot dismiss the question as irrelevant. Those who oppose continued use of 2,4,5-T, base their concern on the data I have presented. Other examples could be included, but the value question is the same. We can and should publicly deal with such value questions. They should be kept foremost in our minds as new compounds are developed, because there is a great difference between carcinogens and cancer, terata or mutagenic agents and simple poisons. If such changes are induced, they may be irreversible. That is to say no recovery is possible even when the offending agent is removed.

We must continually address ourselves to the real world significance of the valid questions raised. We must yield when wrong but persevere when right. We should all remember to use our intellect and reason. Our intellect should help us distinguish between the possible and impossible; while our reasoning powers should help us distinguish between the sensible and senseless. The possible may be senseless.

Opposition to Pesticides

The general public and an increasing number of the agricultural community oppose pesticides. In light of their undeniable efficacy and the wealth of data supporting their contribution to food production in the world's developed countries, why should this be so? Are

these people just opposed to modern agriculture? Do they yearn for a return to "Little House on the Prairie" agriculture without recognizing the drudgery and poverty that went with that kind of agriculture? I don't think so.

Critiques of modern agricultural practice are often superficial, one sided, and lacking in any obvious attempt to understand its complexity. However, it is that very complexity that fosters the critique. Some perceive that modern agriculture has become so complex that it tends to establish its own conditions, to create its own environment and draw us, unknowingly, into it (57). Agriculture performs an essential function. It produces food and we cannot survive without our daily bread. But we do not live by bread alone. We all need a reason or several reasons for living. Humans want more than just biological existence once our needs for food, clothing, and shelter are met. We want a good life which enables us to realize our potential for human development. We want purpose, hope, and a sense of the meaning of things.

Modern agriculture provides abundant food but works against these other things because man is not included in its design. Agriculture has moved from a position of terrifying ignorance and dependence to a place of knowledge and power (57). We are the master manipulators of the environment. We live where we want and eat what we want to when we want it. Pesticides are part of the means used to achieve our independence from nature-and the desirable end of maximum food production.

Our modern agricultural system is beyond the comprehension of most citizens. They feel removed from the source of their food which has become just another commodity. Do farmers grow food or just another commodity to sell? Many agriculturalists will say it is the latter and, if that is so, do people eat food or just another commodity they buy? Our technological triumphs in agriculture have produced an environment and a food supply we no longer trust.

People aren't so much opposed to pesticides as they are alienated from a system



they do not understand and they fear is working against them. We may need to move our agriculture away from maximizing production and profits toward maximizing quality and participation. People may know that pesticides are part of modern agriculture but consumer exposure to them is perceived to be involuntary and people inevitably fear what they don't understand or what they feel is being forced upon them without their participation.

We must discover the means to allow society to maintain control of agriculture's nature and direction. Morrison (57) suggests three things may be necessary to achieve this:

- Members of the society must feel they are participating in the way things

are ordered, that they have the power of choice.

- To make this sense of choosing and participation real, the members of the society must have available the kind of evidence required to judge possible alternatives.
- They must have, beyond the evidence supplied for any particular case, a sense of more general purpose that would serve as a governing context into which particular judgments might be fitted.

These things are not representative of the operative paradigm in agriculture, especially in the pesticide realm. People are not fearful of agriculture which has provided such an abundant food supply for

so long. They fear that part of agriculture from which they feel alienated. When agricultural practitioners appear to be maximizing production or profit rather than human safety, environmental quality, food quality, soil conservation, or maintenance of rural communities and values, people get uneasy about agriculture and its practitioners. It isn't theirs anymore. It is controlled by "them" and they are not "us." The mysterious and omnipresent "they" espouse different values and it doesn't seem right even though most people cannot articulate exactly what it is that is wrong.

Our operative paradigm must be examined to determine why we practice agriculture the way we do. Examination of basic hypotheses may help us understand what happened in agriculture to create unease among the general public.



Chapter Three

The Pesticide Paradigm²

²Adapted with permission from Bulletin of the Entomological Society of America. c. 1972. Entomological Society of America. See reference 83.



The use of natural and synthetic chemicals as pesticides is an ancient agricultural practice. In 1000 B.C., Homer wrote of the pest averting sulphur. In 470 B.C., Democritus suggested that residues from the production of olive oil be used to cure blight. The harmful effects of salt were mentioned by Xenophon in 400 B.C. and the Romans sowed their enemies' fields with salt as continuing punishment (69).

Mercurous chloride was first used as a fungicide for seed treatment in 1755 and Bordeaux mixture (copper sulphate, lime and water) was discovered in France in 1865. It was used then as now for control of downy mildew on grapevines. Selective control of weeds began around 1900 in France, Germany, and the U.S. using sulphates and nitrates of heavy metals. The first synthetic organic chemicals were introduced in 1932 (2-methyl-4,6-dinitrophenol for weed control) and in 1934 (first patent on dithiocarbamates as fungicides).

None of these gained the widespread use and commercial development of DDT as an insecticide and 2,4-D as an herbicide during World War II. These products were inexpensive to produce and sell, easy to use, capable of excellent pest control and apparently safe for all concerned. The development and use of these compounds and the hundreds that have followed have led to the currently operative pesticide paradigm discussed in this paper.

Paradigm

Paradigm comes from the Greek word "Paradeigma" meaning a pattern or example. Kuhn (45) defined a scientific paradigm as "A universally recognized scientific achievement that for a time provides model problems and solutions to a community of practitioners." For Kuhn, the paradigm is not a set of answers or a description of the ultimate destination. It is similar to a road sign which clearly indicates direction but leaves many options concerning the route and precise nature of the destination.

The paradigm does not replace the scientific method nor explain all questions; it defines appropriate questions. For the

scientist, the paradigm and the questions it poses are operative "for a time" and always subject to discussion, further articulation or drastic alteration.

A divergence of opinion and methodology is to be expected. All members of a scientific community work within the bounds of a paradigm which guides their research even though it may not be fully interpreted. Such interpretation often awaits perception of inadequacy or incompleteness.

The community of pesticide scientists is no exception to this generalization. We are an identifiable group because we share common terminology, read the same or similar journals, attend the same kinds of meetings and have received similar training. Our paradigm rests firmly on the historical use of many different pesticides from sulphur to synthetic organic chemicals and the numerous research possibilities their advent introduced. Kuhn (45) states, and his book supports, the contention that "the road to a firm research consensus is extraordinarily arduous." I submit that pesticide scientists, often trained in other disciplines, have achieved a research consensus, and thus a paradigm, which should be explored.

Pest

Many dictionaries define a pest as a plant or animal detrimental to man or his interests. The human element of the definition has been particularly important in the evolution of the pesticide paradigm. That is, pests have been defined by man, not by nature. Nature knows no such category. There is vigorous competition for survival in nature. There are species which succeed and those that fail, but only humans consciously attempt to manipulate the environment to their advantage.

It is man who has created both the category of pest and the tools, from bulldozers to pesticides and fly swatters, which permit manipulation of the environment. We have assumed a right, which some would term an obligation to control. While this concept is commonly accepted by pesticide scientists, it is perhaps less commonly recalled during the practice of pest control.

Although the general definition of pest has not changed, the rising level of concern for maintenance of environmental quality has raised probing questions about its acceptability. It is no longer sufficient to identify a pest. We must carefully define when and where it is a pest and be cognizant that a reduction of pest populations to increase crop yield or protect human health may be the desired end but other ends are also probable. Our definition cannot stop with the general definition of pest which implies our right to control. We must realize the ability to control does not confer a right to control. We need to explore all ramifications of control as well as the tools of control.

The Pesticide Paradigm

The pesticide paradigm includes two fundamental propositions. The first states that there are species that should be classified as pests and that it is necessary to control their populations to produce food and maintain human health and comfort. This part of the paradigm is widely shared because most people really do not like crabgrass (a weed pest) or soft rot of potatoes (a bacterial pest). People are also irritated by mosquitoes (an insect pest) and their health can be irreparably damaged if those mosquitoes carry malaria protozoans (bacterial pests) or yellow fever virus (viral pest).

The second proposition is the less widely accepted inclusion of pesticides as primary weapons in the arsenal of pest control technology. Many would say that pest control exhibits a dependence on pesticides. This accusation usually devolves to an argument rather than a discussion and becomes an irreconcilable issue between proponents of opposite views. It is not my purpose to defend either of these views but rather to examine the basis of what I have posited as the two components of the pesticide paradigm and to examine how the paradigm may change.

The advent of organic pesticides after World War II permitted the development of action programs to control or attempt to eradicate pest populations. Because of the rapid development of pesticides we were able to satisfy a perceived need to control. The species man defined as pests became objects to be studied, understood



(known), and controlled. Studies to understand pest species were often subordinated to studies of pest control. Because of the ability to control, pests could no longer be regarded as components of the environment but as raw material. These studies were good, productive, and necessary science but their objectives were made possible by the development of pesticides.

Knowing the Issue

Pest control studies fit within Kuhn's (45) definition of normal science, i.e., "the activity in which most scientists spend almost all their time." Normal science is "predicated on the assumption that the scientific community knows what the world is like." Tillich (74) has dealt with cognitive relations, what it means to know something, and points out that knowing is an act of union of the subject (the knower) and object (that to be known). Subjects observe objects, interpret them and fit them into their frame of reference. However, the union is an anomaly in that it requires separation or detachment. In order to know one must look at an object and looking requires separation, that Tillich terms a "cognitive distance."

Tillich (74) calls the knowledge resulting from separation "controlling knowledge" which he contrasts with "receiving knowledge" or that which emphasizes creation of union between subject and object. The definition of pest, which separates, and our ability to control have made pests objectives of controlling knowledge. While mankind has resisted strenuously becoming objectified, we have made pests completely conditioned and calculable things deprived of their subjective qualities. They are objects of the knowledge of technical reason which looks upon them and, in a metaphorical sense, does not see them looking back.

Our relationship to pests is one of dominion. It is our destiny to subdue (control) them so the environment will conform to our design. If there is wisdom in the ecology of nature, one must question the possible ends when pests are objectified as they are when perceived only through controlling knowledge.

In contrast, receiving knowledge includes an emotional element that controlling knowledge tries to avoid. Emotion, or the expression of emotional preferences (i.e., values), is the vehicle for obtaining knowledge in the creative union but the vehicle does not make the content emotional, Tillich notes. Content may be rational, verifiable, and received with critical caution. However, emotion is a prerequisite to receiving knowledge because union of subject and object is impossible without emotional participation. It is through union that we achieve logical meaning or understanding. Understanding "involves an amalgamation of controlling and receiving knowledge, of union and detachment, of participation and analysis." (74)

Controlling knowledge dominates the pesticide paradigm and the practice of pest control. Controlling knowledge is precise, publicly verifiable and undoubtedly successful in terms of pest control. Great stores of empirical knowledge have been produced, and research continues to develop knowledge about pests and how to control them. However, controlling knowledge, which only objectifies, runs the risk of losing sight of the element of union and perhaps of real understanding. Pests become what we, and our controlling knowledge, consider them to be. They exist, therefore, they must be controlled. But do they exist only to be controlled? To know how is not necessarily to know why! What is the natural role of what man calls pests, and where is the emotional element in knowing pests and what to do about them?

Pesticide science, working within the proposed paradigm, presents the truth about pests as that contained in empirically verifiable statements, but truth is not restricted to experimental verification and testing by repetition. "Truth is the essence of things as well as the cognitive act in which their essence is grasped." (74) The pursuit of truth requires controlling knowledge, but it also requires receiving knowledge.

One test of truth is the experimental, which the pesticide paradigm has tended to embrace as the only method. It has

avoided or ignored experiential verification as a test of the validity of pest control or pesticide use. Experiential verification, derived from cognitive union, has usually been labeled as environmentalism or emotional (which it is) as opposed to scientific and factual (which it also may be). Such verification often suggests that pests are not just objects to be controlled and that ends other than control are the result of pesticide use. The technical success of pesticides and pest control is an impressive verification of the success of controlling knowledge of pests. Receiving knowledge is not as easily or as precisely verifiable. Life makes the test of verification and it takes longer, is not controllable, and has an element of risk.

Tillich (74) says that "life processes have the character of totality, spontaneity and individuality." Whereas "experiments presuppose isolation, regularity and generality" (74). Therefore, only separable elements of life are open to experimental verification while life itself must be received in creative union and verified experientially to be known.

Thus, within the pesticide paradigm, pests are objects to be controlled. They are objects of controlling knowledge, and pesticides are a means of control. The rise of environmental concern, awareness of the interdependence of life and a great regard for all creatures great and small³ has brought the pesticide paradigm into question. We should recognize that the controlling knowledge, which dominated the paradigm, is verifiable but may not be ultimately significant, while receiving knowledge can be ultimately significant but cannot give the same degree of certainty.

The Paradigm Shift

The shift that is occurring is not tantamount to a revolution. Pests are still recognized as such and the need for their control will continue. The most important questions concern the application of the definition of pest and the use of pesticides as the primary means of control. A 1976 book (50) accurately describes the questions and discusses the limitations

³The title of a best seller. Herriot, James. 1972. All Creatures Great and Small. Bantam Books, 499 pp. Title derived from the well-known hymn All Things Bright and Beautiful by Cecil Alexander.



of science in determining answers. Lowrance begins by stating some assumptions which most pesticide scientists would subscribe to:

- Technology has not been an unmixed blessing and will remain with us.
- Many of our problems are technological in origin but will necessarily be solved in the political, and not just the technological realm.
- Human activity will always and unavoidably involve risk.
- To make a safer world we can start changing only from where we are now.

The development of pesticide technology has brought undesirable side effects as well as great benefits. In spite of conflicting opinion about the relative magnitude of the benefits and risks, pesticide use and development will continue for the foreseeable future and only the unknowledgeable would suggest it stop entirely. Such use will occur in a world of changing values and expectations, a world where "know-why" will assume equal or greater importance than "know-how." What one man regards as weeds or objects of controlling knowledge another may see as wild flowers or objects of receiving knowledge to be appreciated, enjoyed, and lived with. While one man perceives insect pests still another will see a natural order with which we must not tamper casually.

We all want a "good" environment. But who will define what is "good?" The history of pesticide legislation illustrates that those who develop pesticides and those who use the pesticides and the pesticide scientists who think they best know pests and their control, are not the sole possessors of the rules of the game. The public and the political process are involved and probably will become more so.

The definition of what a pest is and when

it is a pest is not solely the province of the pesticide developer, the scientist, or the pestered. Nor do the pestered have the right to invoke a control of their own choosing. The use of pesticides is subject to public review and this is creating pressure to change the paradigm.

During the decades of pesticide development, public health concern in the U.S. has changed from a microbiological to a microchemical one. All who are involved with pesticides are aware of probing questions about carcinogenicity, mutagenicity, and teratogenicity. The U.S. Environmental Protection Agency has promulgated controversial rules for evaluation of the carcinogenicity of pesticides in development.

During the ensuing discussion about environmental safety of pesticides, it has become clear that many miss a point that Lowrance (7) has made clear. The business of the scientist is to answer scientific questions and seek scientific truth. The business of the advocate is to win without violating the law. The pesticide-environmental issue has often become an adversative procedure in which some pesticide scientists bemoan the disregard of what they perceive as facts when the issues seem to be consistently decided by advocates of complete human or environmental safety with little regard for the probability of untoward events and apparent neglect of pesticide benefits.

What these scientists fail to see, as Lowrance has clearly illustrated, is that safety cannot be measured, only risk can be measured. Something is safe if its attendant risks are judged to be acceptable. Measuring risk is an empirical scientific activity but judging safety is a normative political activity. Pesticide risks are measured scientifically but the judgment of safety has been, and should be, made in full consideration of all available ethical, economic, political, and scientific information. The science, i.e., the measurement of risk, may become a secondary or lower issue when the political realm judges safety and thus acceptability.

Such judgments will be made and many current debates center on acute vs. chronic effects. The use of pesticides in the environment has always been predicated on two assumptions (3):

1. Man must eat (and remain healthy).
2. He should not be poisoned now or in the future because he cannot avoid eating.

It has been relatively easy to answer acute toxicity questions. Obviously pesticides (from pesta L--pest, and caedere L--to kill) are poisons. If they were not poisonous to something they would be useless. There are threshold dosages for some pesticides and the mild and serious effects are different for each pesticide. Such acute toxicity levels can be determined in laboratory studies and during use immediate poisoning can be avoided. However, the chronic toxicity question is more complex. Scientists can make predictions, but cannot offer proof that the present use of pesticides will not cause untoward effects at some unknown future date. Analysis of the remote future has traditionally been a prophetic not a scientific activity.

Pesticide manufacturers are required by law to test the carcinogenic and teratogenic properties of products prior to public sale. These tests are conducted on laboratory animals at high dosages. In these tests, is a compound that produces no tumors of any kind in 100 animals or one that produces only benign tumors to be considered non-carcinogenic? Scientists do not agree on the answer.⁴ However, the U.S. Environmental Protection Agency has decided that any risk is too great whether it produces benign or malignant tumors. EPA has promulgated and is presumably acting on the basis of its principles of carcinogenicity (48) which, among other things, state that:

- A carcinogen is any agent that increases benign or malignant tumor induction in man or animals, and
- The concept of a threshold exposure level for a carcinogenic agent has no

⁴ If no tumors are found in 100 animals in a properly conducted experiment, statistical analysis shows that at a 95% confidence level the tumor incidence is less than 4% not 0. [See Weinhouse, S. letter to Ed. C & E News (22)]



practical significance, because there is no valid method of establishing such a level.

Editorials and a series of letters in Chemical and Engineering News (22) have argued the issue and made it abundantly clear that there is an unresolved issue.

These are normative political judgments of safety that have considered the available science but are not scientific measurements of risk. Such judgments are made, usually with incomplete data⁵ in what is understood as the field of benefit-risk analysis. This frequently discussed method of analysis is most often a qualitative rather than a quantitative analysis, for questions of the relationship of pesticides to environmental or human safety.

The problem is judging unpredictable risks of chronic toxicity against benefits which are equivocal. It is often a matter of relying on the opinion of one group of experts as opposed to another, equally well trained and competent group. EPA traditionally has sided with safety, much to the consternation of many who view this as an overemphasis on risk. They see pesticides as guilty until proven innocent, but we should realize that this is consistent with the view that the major pressures to retard economic development are those on the side of safety (39).

Kahn et al. (39) point out that people are more willing to accept deaths (and by implication environmental damage) which are not traceable to specific causes, but only when they cannot identify victims ahead of time, and prevent death. Political decision makers and most scientists have come to the conclusion that damage over time is just as bad as damage in a short time and find this unacceptable. Thus, we find ourselves working within a paradigm that generates controversy between unpredictable risks (chronic toxicity) and benefits which have not been elaborated to the satisfaction of the larger society.

Any modern society subjects its citizens to all manner of risks some of which are

great. Citizens who want the benefits of that society accept the risks as part and parcel of living. (We drive cars--a dangerous activity.) Yet there is something particularly insidious about the unknown risk of extremely small amounts of pesticides that might be in our food, air, or water. It is generally accepted that they cause few acute effects. Still we ask "I wonder if I will get cancer in 20 years?" This is an obviously unanswerable, but nagging question. The majority of society seems to support what EPA does about regulating pesticides, especially when it concerns those unknown but potentially dangerous chronic effects.

Kahn et al. (39) do not question the wisdom of siding with safety but they do provide an example which those who judge should consider. They ask if damage over time is as serious as damage that occurs in one generation. Their answer using the following example suggests it is not.

"Imagine that society must choose between four situations:

- 100 percent of the next generation would be killed.
- 10 percent of the next 10 generations would be killed.
- 1 percent of the next 100 generations would be killed.
- 0.1 percent of the next 1,000 generations would be killed.

In the first case, one has an end of history with everybody dead. In the last case, great damage occurs, yet it is scarcely apparent because it is spread out over such a long period of time and among so many people.

Clearly the first choice is intolerable. The fourth, while tragic and nasty, would certainly be better tolerated under most circumstances. Indeed, in many situations similar to the fourth case, it would not be possible to measure the damage or prove that it existed. Any analysis of the difference between the first and fourth situ-

ation must take account of this spread over time, even though the total number of people killed is exactly the same."

As benefit-risk questions concerning pesticide science will be around for some time, it will behoove us to recognize them and develop answers appropriate to the questions evolving from our new paradigm. As we do, we should be cautioned by the words of Harold Laski (46):

"Special knowledge and the highly trained mind produce their own limitations. Expertise, it may be argued, sacrifices the insight of common sense to intensity of experience. It breeds an inability to accept new views from the very depth of its preoccupation with its own conclusions. It often fails to see round its subject. It sees results out of perspective by making them the center of relevance to which all other results must be related. Too often, also, it lacks humility; and this breeds in its possessors a failure in proportion which makes them fail to see the obvious which is before their very noses. It has, also, a certain caste-spirit about it, so that experts tend to neglect all evidence which does not come from those who belong to their own ranks. Above all, perhaps, and this most urgently where human problems are concerned, the expert fails to see that every judgment he makes not purely factual in nature brings with it a scheme of values which has no special validity about it. He tends to confuse the importance of his facts with the importance of what he proposes to do about them."

How Will the Paradigm Evolve?

As stated, prediction of the future is a prophetic activity. Nevertheless, there are some clear signals that indicate a direction of evolution if not an end point.

If one accepts that agriculture will be practiced on the soil in the open environment for some time to come, there is no reason to suspect that pests will not continue to hinder our attempts to produce food. If pests remain, some means for

⁵This comment is not to be interpreted as a criticism of regulatory agencies or of the scientific method. Action on an issue is usually urged by some interested party but science, with its still incomplete understanding of the functioning of most biological systems, leaves many questions unanswered.



their control will also remain. The present method of choice in many, but not all, situations is the pesticide and it will continue to be so for the foreseeable future.

If one envisions agriculture rapidly evolving away from the open environment or away from soil⁶ the evolution of the pesticide paradigm could occur in a very different way.

I choose the first, presently more plausible, assumption as operative for the next several decades.

Signals indicate more governmental regulation and thus greater emphasis on safety and proof of benefits. This may lead manufacturers to develop pesticides that have more specific action against a single pest, growth state, or biochemical process. New application methods will also be developed to permit precise and accurate placement of pesticides on targets and strict avoidance of spray drift and contamination of nontarget organisms.

A second development furthered by increasing regulation and knowledge is the effort by manufacturers to develop specific biochemical inhibitors. Eventually, pesticides may customarily be developed

by first knowing what biochemical reaction can be blocked to cause pest death or malfunction and then designing a pesticide to do that job. Further development would center on formulation and application of the known biochemical inhibitor. Currently, the empirical screening method is used in which many chemicals are tested to see if one is active and selective against a pest or series of pests. Only when this is determined, does one ask how it works. Empirical screening is not a bad method. It is the best available. Its replacement does not depend on the willingness of manufacturers to adopt the method proposed, but rather on the development of sufficient biochemical data so the method can be used. The reason we do not have a herbicide that interferes with cellulose synthesis (a specific plant process) may be that we do not know precisely how the plant synthesizes cellulose.

The paradigm also will be modified by greater use of what pesticide scientists know as “integrated control.” This is defined as the use of cultural, mechanical, chemical, and biological control methods, in an appropriate combination, to maximize pest control. The concept is good but it is hard to invoke because we do not know how each practice or their many combinations will affect specific

pest populations in all environments. As this knowledge is developed most pesticide scientists are confident that integrated control will reduce (but may not eliminate) pesticide use.

Finally, I think pests must be increasingly understood, not as objects of controlling knowledge, but as objects of receiving knowledge; living things with which we share an environment. The paradigm of pesticide science may be evolving in the same direction as medical science. Some pests (e.g., smallpox) are regarded as so serious that eradication is the only acceptable answer. Other pests (e.g., poliomyelitis virus) are regarded as so serious that they must be prevented. The physician’s paradigm, and knowledge, permit practice of preventive medicine rather than just curative therapy.

Pesticide scientists have been constrained by limited knowledge of pests and host biochemical function. They are also constrained by a paradigm that defines pests as objects to be controlled and subjugates understanding to control. This forces the practice of primarily curative rather than preventive therapy. As our knowledge progresses and we recognize the limitations of our value system, our paradigm should evolve toward preventive therapy.

⁶Although irrational to many traditional agriculturalists this is not, strictly speaking, impossible. One must consider the pressure of rapidly expanding populations on agricultural land and other relevant events like the cheap desalination of sea water and what that might do to develop hydroponic agriculture. See reference 39.



Chapter Four

A Question of Faith



The purpose of this essay is to describe the current practice of weed science in its historical agricultural context (Chapter 1), discuss a value issue (Chapter 2), discuss the dominant paradigm of weed science (Chapter 3), and in this chapter to question the agriculturalist's basic faith in the possibility of perpetual increases in production and in ever more efficient herbicides.

Others have questioned adequately the western world's unalloyed faith in technology and production (12,21,32,81) and how this view has affected our agriculture (12,13). This essay focuses on pesticides as one aspect of western agricultural technology. Its specific intent is to question the conventional agricultural wisdom about pesticides by drawing examples from weed science.

The conventional wisdom about anything is that which "sets great store by what it calls constructive criticism. And it reserves its scorn for what it is likely to term a purely destructive or negative position. In this, as so often, it manifests a sound instinct for self-preservation. The attack on the conventional or accepted thought is dismissed as an inferior and, indeed, a wanton activity and, as such not something that should be taken seriously." (32)

Within agriculture, the conventional wisdom is that pesticides are useful, if not necessary, tools of modern technology and can be used intelligently. It is often pointed out that the problem is not the pesticide per se, it is the people who use them. The argument that guns don't kill people, people do, is similar. These, often unexamined, points of view are framed and bound by experience, reinforced by the supporting community, and those secure in their possession of the conventional wisdom are not inclined to solicit or accept contrary views. The conventional wisdom is frequently a biased examination of selected scientific data or opinions about what the data say without recognizing that science is not capable of answering all questions and that data are developed by practitioners who are not always aware of their own paradigm and bias.

This is an attack on the conventional wisdom about pesticides. It is not an attack on data about pesticides, but on attitudes toward data and conclusions drawn from it. Indeed, part of the basic premise herein is that arguments are not just about data. Arguments are often about subjective interpretations of data and these should not be dismissed because they lack objectivity. They appear on both sides of the issue. Therefore, this is an attack on attitudes and thinking, what some like to call "the mind set" of agriculture and agriculturalists.

Pesticide is a word which evokes many images, especially concerning their associated risks. College students ranked them fourth on a list of 30 most risky items in 1982. Members of the League of Women Voters ranked them ninth, and business and professional club members placed them fifteenth. Actually, when the number of accidents per year was considered, pesticides ranked 28th out of 30 known risks; between food preservatives and prescription antibiotics (77).

The number of accidents recorded per year is, of course, a precise quantitative measure and those who know the techniques can evaluate hazards and measure risk based on such quantitative data. Most people, however, rely on intuitive risk assessment which, by definition, is not a precise quantitative measure. Their information comes from news media, friends, and most certainly, just "feelings" (67). The dominant feeling among Americans is that they are more at risk from pesticides today than they have ever been before. They feel the situation is getting worse, which is in marked contrast to how professional risk assessors view pesticides (67). These assessors see the most attention paid to risk reduction while others see the exact opposite. Defenders of pesticides see enormous effort expended to assure that nothing goes wrong but almost no effort devoted to making sure things go right.

Part of the problem is that people don't believe the numbers. They don't believe what risk assessors and obvious advocates present as objective evidence. Tragedies, such as airplane crashes, fish kills from pesticides, or the threat of AIDS

overwhelm most people. Actual data aren't as influential as real and truly scary events. These lead one to assume life is getting riskier. Also people find it difficult to acquire and comprehend data on pesticide safety. Such data are not published in the things Mr. and Ms. citizen routinely read. The data, based on tests of laboratory animals and important assumptions about unity of biochemical response among species, involve extrapolation of results from small test populations of animals to large human populations. When presented with such data people don't understand them nor do they easily accept proposed actions based on them.

The public is further confused and made suspicious when they learn scientists don't agree on the validity of underlying assumptions and have contrary interpretations of the data. The people's competence and wisdom are questioned by rational scientists who believe the underlying assumptions and support proposed actions. Scientists see irrational fear, not supported by the data, from people who smoke, overeat, and consume too much alcohol. The scientifically rational mind wonders why those who ignore obvious health effects of known hazards are so fearful of potentially less harmful but not completely described effects of hazards like pesticides. Are people really that irrational? Perhaps their attribution of unknown but possibly large potential damage to pollutants like pesticides alleviates personal responsibility for a poor life-style or relates poor health to unavoidable external pollutants and relieves one of direct responsibility for personal and environmental health. It may also be true that the data are presented in such a way that they are incomprehensible to most people and their incomprehensibility increases fear. Finally, there is a fear of involuntary contamination and possible consumption of pesticides with uncertain effects but acknowledged toxicity.

The problem is also related to the fact that disagreements about risk do not always disappear in light of new scientific evidence. Strong feelings are not always overwhelmed by contrary scientific evidence. Evidence which agrees with one's preconceived notions is usually immedi-



ately accepted and science's credibility is enhanced. But when scientific evidence is contrary to personal and deep-seated emotional beliefs it often may be dismissed as erroneous, unreliable, or biased by its source of funding (67). Entrenched societal and culturally based beliefs are difficult to change when they affect personal health and safety.

The Quality of Evidence

In 1917, Gustav Holst composed "The Planets," his musical description of seven of the nine planets in our solar system; omitting the Earth and Pluto.

An image of each planet is created in our mind as the music evokes thoughts, feelings, and emotions. What we hear is common to all listeners but what feelings or images the music evokes varies with each listener's prior perception of the planet and an innate or acquired ability to appreciate music. Not all listeners feel the same way or create the same mental images even when they listen together.

Holst portrays Mars as the bringer of war who is forceful and assertive. Venus is the bringer of peace and a lover of all beautiful things. Mercury is musically the winged messenger, quick in thought and ingenuousness. Jupiter is buoyant and hopeful, the bringer of jolliness. Saturn is patient and enduring, the bringer of old age. Uranus is the magician, abrupt, eccentric and unexpected, while Neptune is the subtle, mysterious mystic. Each of Holst's images was inspired by stories of the planet's astrological character and not by any hard scientific evidence of what they are "really like." We are inclined to accept Holst's vision of the planets because most of us don't know them very well and are willing to let our imagination be led by Holst and his music. We revel in our emotions and ignore scientific evidence to the contrary.

In the scientific realm, we are prevented from giving our emotions or the emotions of others credence on strictly scientific issues. Their proponents argue that pesticides are creations of science and must be judged scientifically, not emotionally. This rule is applied to all questions about pesticides and other evidence

is dismissed. Weed scientists are, perhaps unknowingly, converts to logical positivism which tests all statements by reference to experience or the structure of language. Critiques which don't fit the language or experiential expectation are rejected. This creates separation from other opinions and dismisses outside, non-scientific, criticism. This separation did not begin with weed science or agriculture. It has been and will continue to be a scientific and societal problem.

Mayer and Mayer (54) offered an agricultural commentary in 1974 that began with a premise, acceptable to most agriculturalists, that most Americans were ignorant of agriculture. I suggest they still are and that agriculture is regarded as a quaint but not wholly necessary enterprise.

Agriculture is the most basic industry and an essential science, but it is isolated, and in large measure has isolated itself, from the mainstream of American life and from intellectual life. The success of agriculture is fundamental to the success of our life-style, our economic system, balance of payments, and, perhaps of most importance, our survival. We must eat to live. American agriculture takes pride in the frequent assertion that the American farmer feeds himself and over 50 other Americans plus about 30 (depending on whose estimate you want to believe) non-Americans to whom we sell, or occasionally give, our surplus food. Ours is an abundant agriculture, but Mayer and Mayer (54) state that its success has been built on a remarkably well-integrated, self-contained system that has become a model for a world wanting agricultural development but may prove to be a tragedy for the United States.

The current economic disaster of agricultural overproduction is a triumph of applied agricultural science and a prime example of the simultaneous success and fallibility of technology. United States agricultural science and technology, the land grant system of agricultural research universities and experiment stations, and our agricultural extension system are models for many of the world's countries but are also a cause of our present over-production and the farm crisis. Science

and technology, government policy or lack thereof, and social forces caused our farm problem and government is forced to deal with it. The scientific system that helped create the farm problem does not accept any blame for it and therein is part of the tragedy, an example of the agricultural mind set, and justification for Mayer and Mayer's (54) accusation.

Their second premise did not fit the experiential expectation of agriculturalists and, therefore, has not been integrated into agricultural thinking. It is that the integration and isolation of the system have led to what Mayer and Mayer (54) called "the island empire." They suggest that agriculture is an intellectual and institutional island. It is a vast, wealthy, and powerful island, but definitely an island. As United States agriculture developed in the 19th century, it did so independent of other developments and traditions. Agriculture grew up to create its own federal department, extension service, research establishment, professional and trade organizations, publications, and public constituency. These have all endured and enforced agriculture's isolation from mainstream American life. The problem now is exacerbated by a declining United States farm population and consequent erosion of the, formerly strong and cohesive, agriculture political base. It may now be safe for a national politician to ignore the agricultural constituency.

Mayer and Mayer (54) strongly accuse American agricultural colleges of being anomalies within their own universities. They are separated from the mainstream of American scientific thought and university and national discussions concerned with social policy. Because of agriculture's isolation, it does not ask for or receive outside criticism. That situation has contributed to the already described pesticide paradigm (83), our single minded, unquestioning devotion to pesticides as the appropriate cure for all pest problems. When outside criticism of agricultural practice has been offered, it is rarely regarded as constructive and usually its validity is denied because the critic is not an agriculturalist (Mayer is a nutritionist) and, therefore, cannot understand agriculture. Agriculture thus proceeds on



unquestioned assumptions that are challenged most seriously by rigorous, external questioners. This is as true within agricultural colleges as it is among farmers, ranchers, and employees of agribusiness companies.

The result is isolation of agriculture's specialists and practitioners from the scientific and liberal arts mainstream of intellectual life, within their own, self-reinforcing, internal and external organizations. As Berry (11) and Laski (46) suggested specialists place themselves in charge of one possibility by leaving out all others, make rigid, exclusive boundaries and reinforce their image of control and the fiction of absolute control of the agricultural environmental becomes possible.

The myth of absolute control is another aspect of agricultural thought that must be examined. Agriculture, and particularly specialists who work with pesticides, must recognize that the fiction of absolute control may inhibit progress of the world's most important human activity--food production. The fiction of control raises two questions which remain unexplored within agriculture. First, one must question if it is possible to control all species but the crop in any field? If we assume the answer is yes because of our technological wizardry, then we must ask if we should attempt to achieve absolute control. Ought we do what is technologically possible? Is it right for agriculture, the environment, or for our collective future? These are not easy questions to answer. In many cases the first question can be answered with a clear yes. We can do it, at least in the short run, in the present crop-pest environment. The second question often has a clear answer, but it seems totally dependent on the bias of the respondent. The answer does not result from a dispassionate analysis of what we ought to do but from a passionate opinion.

History and the Future

Weed scientists need to understand their past and examine their previous assumptions in light of their history, check the boundaries of their thinking, and, then at least, think about the influence of their perception of absolute environmental

control on the way agriculture is practiced. When weed scientists know their history and comprehend how it governs their choice of control techniques they may be more able to shift from the present dominant chemical control orientation to weed management programs that include but are not dominated by herbicides. Many will greet my request for historical understanding of weed science as no more than a plea for the past and a rejection of the achievements of advanced herbicide technology. Many will also reject my hypothesis that weed science is dominated by herbicides.

I suggest weed scientists should deal with the paradox that while advancing technologies may make present techniques obsolete, they also may revitalize older techniques. For example, computers may allow us to regain a measure of individual freedom and abandon assembly line regimentation. We also may be able to decentralize and disperse work places rather than concentrating them (30). I don't recommend re-inventing the agricultural wheel. I want to explore dispassionately where we are in weed science and how we got there. I want to question the technology that moved us to the level of weed control we can now obtain so easily and rediscover the obvious that has been abandoned as technology has roared on. Forgotten obvious agricultural things, such as crop rotation, may well be worth rediscovering.

"Yes, what you are saying is all very well in its way. No doubt it would be noble to harden ourselves and do without aspirins and central heating and so forth. But the point is, you see, that nobody seriously wants it. It would mean going back to an agricultural way of life, which means beastly hard work and isn't all the same thing as playing at gardening. I don't want hard work, you don't want hard work--nobody wants it who knows what it means. You only talk as you do because you've never done a day's work in your life, etc., etc." G. Orwell, *The Road to Wigan Pier* (60)

Orwell (60) was commenting on the socialist critique of progress. He was a socialist criticizing what he saw as bad about socialism and was specifically

commenting on those hostile to a machine-dominated civilization. His words sound like what those who espouse the conventional wisdom in the agricultural community may say to one who advocates rediscovering and exploiting the value of techniques technology has diminished such as crop rotation, cultivation, careful land preparation, and multicultural crop environments. These techniques should be examined while simultaneously advancing current, excellent work on chemical control techniques, allelopathy, biological weed control, and integration of methods. A portion of the conventional wisdom holds that old techniques have not been abandoned, only added to. This must be questioned.

No one wants to return to early 20th century agriculture. But we should not calmly abandon what we once knew, just because it is old, for new technology that offers tremendous advantages but may demand acceptance of serious problems. The best technology, whether new or old, will solve a problem and contribute to the solution of other problems rather than solving a problem while creating a series of new problems (12).

There is no scientific or social requirement that every technological innovation, every new herbicide, and every dream of technological achievement must be indulged. Some technological achievements are becoming proscribed because of their real disadvantages; and others because of their perceived disadvantages. Pesticides have faced serious regulatory challenges and the public is, at best, uncertain about them. Therefore, their continued development may be further proscribed and unquestioning allegiance and advocacy will deter continued agricultural development and inhibit continued progress of weed science.

I suspect that most weed scientists do not appreciate the extent of our collective commitment to herbicides as the best solution to weed problems. For example, review of weed science textbooks reveals that over half of each of the currently popular books is devoted to use of herbicides for weed control, herbicide mode-of-action, and herbicide-environment interactions. The Journal Weed



Science shows the same trend. In ten issues appearing from January 1986 through July 1987, a review of paper titles reveals that 56% of the 276 papers dealt with some aspect of herbicides. The next highest percentage of papers was on weed biology and ecology.

Papers presented at the annual meeting of the Weed Science Society of America show a similar trend. In 1985, 65% of the 319 papers presented were on herbicides and in 1987 and 1988 62% and 67% were. Again weed biology and ecology were next highest with 15.7, 13, and 19% in 1985, 1987, and 1988, respectively. The society might be justifiably accused of being the herbicide science society rather than the weed science society. Discussions and thought are dominated by herbicides not by weeds or perhaps it is more accurate to say they are dominated by weed control and one major technology for achieving it.

"Despite much propaganda to the contrary, there can never be any serious question that pest control chemicals and food-additive chemicals are essential to adequate food production, manufacture, marketing and storage, yet without continuing surveillance and intelligent control some of those that persist in our food stuffs could at times conceivably endanger the public health." (6)

Almost all weed scientists and probably the great majority of pesticide scientists would immediately agree that there can never be any serious question that "pesticides are essential to adequate food." Those who so readily agree may not notice the paradox in the quote and their ready acquiescence. There is much propaganda (a euphemism for misinformation or false, non-scientific, emotional critiques) for and against pesticides and their use. Advocates assume their continued use is essential as the quote maintains. There are questions but advocates of essentiality believe questions will be answered by continued application of the scientific method by competent scientists. It is accepted, by all parties, that without continuing surveillance and intelligent control, public health could be endangered. Science, advocates assume, will answer the serious questions that

arise. There is trust that our extensive (some advocates say oppressive) government regulatory scheme will be intelligent and do the necessary surveillance to avoid problems that could, but, it is hoped, won't occur. Advocates thereby make the error Berry (11) accuses them of. "Agriculture experts and agribusinessmen are free to believe that their system works because they have accepted a convention which makes external and, therefore, irrelevant, all evidence that it does not work. External questions are not asked or not heard, much less answered."

When there is a finite possibility that some pesticides could persist in our food-stuffs and "could at times conceivably endanger the public health (6)" a very serious question exists, and its validity cannot be denied by invoking the essentiality of pesticides.

In light of the public's poor understanding of their relationship to food production, manufacture, marketing and storage to suggest "there can never be any serious question" about their essentiality is irresponsible. Suggesting that "continuing surveillance and intelligent control" will prevent continuation of any technology's problems flies in the face of common sense. The public is regularly notified of fallible technology, to wit:

- Pesticide related industrial plants that explode and kill 2500 people and injure at least another 150,000 in Bhopal, India.
- Pesticide (Temik--an insecticide) contaminated water-melons in California.
- Pesticide spills in the Rhine River.
- Agent orange and its not completely known but potentially devastating effects.
- 99% of all deaths due to pesticide poisoning occur in the world's developing countries, where only 20% of the world's pesticides are used.
- Exploding nuclear power plants (Chernobyl, USSR).

- Planes that come apart in the air, don't stay in the air, or collide when in the air.
- Space ships that explode in the air.

Continued professions of faith in technology and statements that more will cure present problems are not accepted by an increasingly dubious public. Weed scientists, like all technologists, profess too much faith in their dominant technology and fail to recognize that the general public sees all technology as related. Weed scientists fail to understand why the public is so skeptical or to appreciate the public's perception (perhaps the reality) of the awkwardness and inefficiency of institutions designed to monitor modern technology. We should not dismiss our critics with the epithet "emotional propagandists." There are many serious and intelligent questions and we need to listen to them, understand their origin, and address them completely and responsibly. We must persevere when correct, yield when wrong, and know how to choose which course to follow. We must also recognize that some questions cannot be answered once and for all. Questions about environmental and human safety will persist because they are inherent in technology. They must be addressed. The best answers may be from those that recognize the nature of the question and its origin in real human concerns that all share. We must not patronize or reject the question and thereby the questioner.

The public regards science as a source of facts rather than a process. They also seem to believe that only the initiated can really understand all the facts required to make good, wise decisions. Public dismay occurs when even the scientists who should know cannot agree on what the facts mean or what ought to be done because of them. How can scientists and technologists expect us to believe their ways will lead us out of the wilderness to salvation when after several decades of spectacular achievements we are more anxious, feel less safe, have a more polluted environment, and live in a world that is not at peace? We live in an age of anxiety and science and technology often make us more, not less, anxious.



They are one important route to the future and certainly a key to continued development and progress. They are a necessary but not sufficient part of solving the complex problems we face.

The pharmaceutical industry has been accused of conditioning doctors and patients to believe that the human body needs continued medical supervision and drug treatments to stay healthy (21). Many believe the petrochemical industry is equally culpable of conditioning farmers to believe that soils and crops need additions of chemical pesticides, supervised by agricultural scientists and technicians, to be productive. In both cases these practices have (but do not always) seriously disrupt the natural balance of living systems and thus generate unease and numerous diseases (21). For example, an estimated 1.5 to 2 million people in the world's developing countries suffer acute pesticide poisoning annually, and pesticide related deaths (primarily in developing countries) are estimated to be 10,000 per year (61). The world's developing countries currently use about 20% of the world's total pesticide production, with consumption heavily concentrated in Brazil, India, and Mexico. Average annual pesticide use in developing countries is about 100 grams per person, much less than in developed countries. However, imports are growing rapidly and annual use is increasing (55). Proposed benefits of pesticide use are great but there are large social and environmental costs. Human poisoning is clearly the highest price paid for expanded pesticide use (55). Pesticide intoxication is a real but not widely acknowledged public health problem to which the United States contributes by exporting about 400 million pounds of pesticides each year.

A complex mixture of facts, accusations, and well-documented reports of malpractice and environmental damage or human injury serve to harden public attitudes about risk and increase the burden of government regulation which the pesticide industry blames for hobbling prospects for its research based progress (7). The world's major pesticide producers spent about \$410 million on research and development in 1985 which was about 8.9 percent of farm sales (\$4.6 billion)

and 6.2 percent of total sales (\$6.6 billion). As part of this complex mixture, the thalidomide tragedy, led the public to believe that drug companies were not staffed exclusively by saintly scientists and increased public demands for legislation to prevent future tragedies (7). Public awareness of DDT/DDE, dioxin, Bhopal, and other pesticide incidents also are part of the mixture and are automatically linked to thalidomide. The public assumes other tragedies will follow.

Perception of Risk

People seem willing to accept higher risks from activities perceived to be highly beneficial. Thus, we drive cars willingly although risk is very high. The possible hazard of DDT/DDE in the daily diet of the average United States citizen is equivalent to that of the chloroform (a known carcinogen) actually present (about 83 ppb) in one glass of average United States tap water. It is insignificant compared to natural carcinogens in our diet (4). We also know that coffee contains the known natural carcinogens hydrogen peroxide and methylglyoxal at about 4000 ppb while cola drinks contain the known carcinogen formaldehyde at 7,900 ppb. Beer contains known carcinogens and alcohol consumption can cause human cancer. Perhaps most shocking, milk, with its high percentage of fat, may be implicated in human breast and colon cancer both associated with high fat consumption. These facts are used by pesticide advocates to support pesticide use which, they maintain, is less hazardous than many commonly encountered and routinely accepted things.

Research by Slovik (67) suggests that there is wisdom as well as error in public attitudes and perceptions. The "basic conceptualization of risk is much richer than that of experts and reflects legitimate concerns that are typically omitted from expert risk assessments."

Slovik's data (67) show that pesticides are unknown, by which he means they are not observable to those who may be exposed, their effects may be delayed, and the totality of risk may be unknown to science. He also categorizes them as dreaded which means they are generally regarded as uncontrollable, often fatal,

not equitably distributed, have a high probability of risk to future generations, and are not easily reduced or mitigated once in the environment. A dread risk may be one which is increasing with time and is involuntary. Hazards judged to be voluntary (driving a car, riding a bicycle, smoking, using a home lawnmower) tend to be judged as controllable. Pesticides in Slovik's opinion are involuntary risks which are unobservable, of certain hazard, perceived to have delayed harmful manifestations and are, therefore, regarded as uncontrollable.

The pesticide advocate often responds to this kind of risk analysis by requesting a rational look at all the data and a complete examination of risk *and* benefit information. Advocates find it difficult to accept that the most reasonable assumption about people's behavior is that there is some method in any apparent madness (29). Weed scientists rely heavily on logical positivism and their intuition which they are sure is based on objective evaluation of all important data.

Pesticides also suffer from the negative image shared by large companies whose activities are suspect perhaps only because they are large, not personally controllable, and remote from common experience. Pesticide companies are accused of selling dangerous and unnecessary products in developing countries that do not or cannot regulate markets (19,79). The companies plead not guilty because they are providing materials developing countries need to develop. They argue it would be unacceptably intrusive of them to deny access to potentially beneficial technology and to presume they can or should do what countries ought to do--govern local use with adequate regulation and intelligent supervision. The industry is also accused of overcharging for products and using people in developing countries as guinea pigs to test products that cannot yet be sold, may never be sold, or can no longer be sold in developed countries. However, in terms of the industry's image, it now matters little whether or not these accusations are true. They are believed (7).

There are many parallels between the pesticide dilemma and the nuclear power



industry's dilemma. Both are widely feared, both suffer from nearly universal misconception about what they are and can do, both have generally acknowledged dangers, and advocates of both say that unnecessary and increasing governmental regulation is hampering continued development. They also share widespread public disagreement over present policy and interpretation of danger.

What should be done when experts disagree even about problem definition? In view of the fact that the public believes the pesticide chemical industry is guilty as charged, Prior (62) questions whether today's scientists can maintain allegiance to the ethical imperative of searching out the truth. He suggests that scientists should seek truth but have a unique moral obligation to reflect on implications of their discoveries, to inform others, and to search for answers to new questions created by science's undeniable impact on public issues.

Scientists express their values as they choose what problems will be studied and what methods will be used to study them. Many agricultural scientists resist this challenge and do not speak out in the public arena about their work and its meaning because they are reluctant to be perceived as reaching beyond their area of technical expertise--their island. They also see public debate as inevitably political and as an unknown, contaminated arena. However, policy makers will make decisions based on poor science or with a poor understanding of science unless scientists are willing to speak individually and collectively. Thus, agricultural scientists, including weed scientists, are not value free and certainly are not morally superior. We succumb to the vices and possess the virtues of ordinary people in about the same measure and the public knows it. We are viewed as performing a function that can (and should) be judged in a social context and evaluated according to the ends served.

Scientists have different opinions about scientific matters. Indeed it is the essence of science that it be a publicly verifiable activity and debate within the community of science is essential to verification. The scientist's judgment is influenced by

political and other biases. For example, much science now is not publicly verifiable when it is conducted in secret because of its source of funding, proprietary nature, or potential patentability. The absolute virtues of science and the scientific method are effective only where the matters at issue are absolutely scientific (62). In the debate over pesticides and nuclear power, the questions and answers are not absolutely scientific and are debatable.

Determining what issues are absolutely scientific is not easy. Prior (62) points out the facts about nuclear fallout were known to both sides of the debate and radiation dangers were agreed upon long ago. Differences arose about whether dangers all agreed were real, were slight or great, and if inherent risks were presumed to be necessary and slight or unnecessary and great.

The same differences occur in arguments about pesticides. The established facts about their physical and chemical properties, their activity and selectivity, their use and misuse, and their hazards have been reasonably well established for some time. The disagreement is over their essentiality, especially in agriculture, and whether risks attendant on their use are necessary and slight or unnecessary and great. As a consequence, nuclear power arguments have shifted to issues that bear only indirectly on scientific answers (62). The same is true for pesticides. It is argued that continued reliance on pesticides as the front line of defense against pest-caused reductions of crop yield or possible injury to human health is necessary to maintain the quantity and quality of our food. Although there are risks, the argument goes that acceptance of such risks is not unusual. Any possible increase in cancer or environmental pollution from continued or even expanded pesticide use is more than offset by the advantage of increased food production and environmental quality in a world where too many people are not fed adequately. Appealing to our faith in technological progress and a better future, these are offered as scientific arguments. They are not scientific arguments. The decisions they support are not scientific decisions (62). The reasoning is by analogy

and the argument is a moral one that supports a moral decision. (There is hunger in the world, we can help, and ought to do all we can.)

Discussions of the necessity of herbicides and other pesticides for continued agricultural progress are not debates about scientific evidence. They are value-laden arguments (on both sides) and must be addressed as such. Scientific evidence sometimes is essential but just as often it may muddy the process up and make resolution more difficult. The presence of known carcinogens in our drinking water, beer, or milk is interesting, but not immediately relevant especially when presented to demean or ridicule those who oppose pesticide use because of possible health hazards.

Weed scientists like other scientists must have funds to pursue their work. The public often wonders whether we are seeking truth or funding. In his 1961 farewell address, President Eisenhower warned us about the military-industrial complex that had become a fulcrum on the American political scene. He then went on to attack education's role. The university, "the fountainhead of free ideas and scientific discovery, has experienced a revolution in the conduct of research...A governmental contract becomes virtually a substitute for intellectual curiosity."

If that is the public's general perception of the academic community is it any wonder that our arguments in favor of, and our demonstrated allegiance to, a particular production technology and its risks are greeted with suspicion about our true motives?

The Problem

Weed scientists may be akin to the Sorcerer's apprentice, unable to control the forces unleashed. Perhaps we are modern Captain Ahab's, all our methods are sane but our goal is mad. How much control can we logically achieve? Can weed scientists achieve almost any degree of control they want and what should they want?

Do weed scientists suffer from the same excessive faith in their expertise (11,46)



that all experts may have? Do they neglect all evidence that does not come from within the ranks?

Do they fail to see the values inherent in their decisions and the actions taken based on those decisions? Do they confuse the importance of facts about herbicides and weed control with the importance of what they propose to do with facts they choose to accept?

If one or more of these things is true, what should be done about the problem? Some may argue that these attitudes and the results do not define a problem. I disagree.

The best long-term solution is to change people's attitudes and values. Environmental education which justifies rights for rocks (59) tends to discredit the confidence that a technological fix exists for every problem.

The quest for environmental quality and long-term stability has run counter to the growth oriented American ethos. Our nation has been growth oriented since its inception and it is time we explored our dependence on economic growth and the world-wide imperialism it generated and continues to foster. Our growth ethic has demanded environmental rapaciousness and wholesale neglect of the environmental consequences of economic development.

Collective world progress, and perhaps real world peace, await substitution of ethical for economic criteria in the calculation of human and technological impact on the world and on others (59). We abuse land and, therefore, ourselves because we regard land as a commodity which belongs to us rather than as something to which we belong and care for temporarily. Aldo Leopold told us that "a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." (47)

Weed scientists have not learned that lesson well and do not use this ethical standard when economically based control technology is developed. Values of the right to existence of the unknown or

inanimate are among the latest moral acquisitions and they are not widely held in halls of weed science nor are they pervasive in agriculture.

Agriculturalists are secure in the correctness of their views because they constantly share them with each other. When they speak outside familiar circles they often become frustrated. It is easy to blame the recipient of a message for an inability to understand (38). Perhaps they are scientifically illiterate or so committed to their own narrow view that they either cannot hear or choose to ignore the clear logic of our view. It is so much more comfortable to speak to those who understand our language and know the wisdom of our words.

Issues of Fact and Value

Separating issues of fact from issues of value is fundamental to intellectual hygiene (29). In the pesticide debate, we are often faced with those who are willing to give quick, easy definitive answers to complicated questions. These answers often go beyond available data and pesticide advocates quickly label them as emotional arguments. Often they are. But, emotion does not always symbolize error and often carries the debate in spite of an evenhanded scientific approach.

Debaters often do not really speak to each other because they have not separated issues of fact from issues of value (29). Furthermore such a separation is not always possible because there is no clear distinction. There may be values within facts and vice versa. Beliefs about the facts shape values and those values, in turn, shape the facts we search for and how we interpret them when we find them (29). Knowing this abstractly still means we may be bound by our education and traditional ways of defining and studying problems (29).

Scientists pride themselves on objectivity but it frequently has a subjective dimension that assumes we are correctly addressing the right problem. We assume that we have issues of fact and value sorted correctly. Acquisition of objectivity is further complicated by definition of the right problem and acceptable solutions. One hopes the best solutions

will be defined as what is in society's best interest, not by what is in the best or exclusive interest of one party to the debate (29).

Debates about pesticides will continue. It is my hope that weed scientists will see that it should not be their purpose to win such debates. Attempts to win are doomed to fail. Winning means someone else has lost and in value issues proving someone else wrong does not prove your side right. It is our burden to define risks and benefits and then discuss acceptability of risk in light of benefits. This is not an easy task and one many scientists are ill-equipped to do. There are no universally acceptable risks and the lowest risk option may not be best for all (29).

Issue Resolution

Resolution of pesticide issues is complicated by at least three major dilemmas (28). The first is a lack of complete scientific evidence concerning basic environmental and human health implications of pesticide use. We know a great deal about how pesticides act and how they can be used to maximize their activity and selectivity. We don't know enough about what many consider to be more important questions. The complete fate of a pesticide chemical after it leaves its point of application cannot be described except in general terms. We know transport occurs, but we don't know how far, in what form or what the complete path of degradation/metabolism is. Nor do we know the complete eventual fate of an applied molecule and its metabolites.

Groundwater contamination by pesticides is now a major public and scientific issue and is being addressed competently in many research laboratories. It has always been of concern to pesticide developers, but those involved in pesticide development (not just the original manufacturer) did not act swiftly to prevent problems although they now are working vigorously to solve identified problems.

The second dilemma (28) is the difficulty, or perhaps even our inability, to evaluate fully the social and environmental costs of inevitable pesticide effects on human health, non-target organisms, on water, soil, and air derived from



agricultural use. The question has been lost in the quest for increased sales and efficient pest control.

The third dilemma (28) complicating final resolution of these issues is the inadequacy of institutions designed to allocate costs and resolve issues even after adequate problem identification has been achieved.

The public has come to recognize that each advice giver has particular strengths and weaknesses and should not be allowed, independent of other advice givers, to make societal decisions (29). No one view can fully present or assess the impact of pesticides at their point of use and their present and future impacts.

Risk management is too complex and too risky to leave to experts. Experts are necessary because of their expertise, but it is not sufficient to allow them to make all final decisions and assume they will make the best decisions for all.

Pesticide use is coming to be recognized as more than just a crop production decision that a farmer and advisor can make. There are too many ramifications that go beyond site and intended use.

Weed scientists and others in agriculture must participate in use decisions but not presume to make them solely within a context of crop production. Weed scientists and their colleagues in agricultural science have essential information and insights to offer but they may not have the correct answer to all questions. Admitting relative ignorance may make science and scientists more credible and allow them to continue to make outstanding societal contributions through enhanced food production and environmental quality.

One way to do this is to continue development of more systematic approaches to weed management rather than place even more reliance on weed control to solve all problems. We would not tolerate for long a medical or dental practitioner who willingly cured disease once we were sick but failed to emphasize disease prevention. Most people intuitively un-

derstand that it frequently is easier, healthier, less expensive and more pleasant to prevent a disease than to cure it once it has attacked. Children in the developed world routinely are immunized to prevent contraction and spread of contagious diseases because most parents recognize the serious health consequences if measles, infantile paralysis, or diphtheria are contracted.

We do not know how to vaccinate an agricultural field to prevent insect, disease, or weed infestation. However, one thing all pest control specialists can be justifiably criticized for is stressing control technology while giving only minor attention to preventive technology. Fryer agreed when he pointed out (31) that herbicides have provided a powerful tool for weed control, and their great efficiency has enabled intensive agriculture to develop. It is not appreciated that emphasis on chemical control technology has generated new weed problems which seem to require more complex and intensive herbicide treatments. In this system, which dominates developed country agriculture, reliance on herbicides has become complete (31). Fryer (31) asks these questions which lead to the conclusion of this essay.

- “Has reliance on empirical use of herbicides as a substitute for the mechanical and cultural methods of weed control formerly practiced gone too far?”
- “Might not greater efficiency and cost-effectiveness in crop production be obtained if cultural and chemical methods of weed control were to be harnessed more positively to work together?”
- “By a better understanding, through research, of the weeds themselves, of their ecology, of the constraints they impose on crop production, and of the factors influencing population trends in particular cropping regimes, could not a more rational approach to weed control result in greater economy in the use of chemicals and improved environmental quality or, where herbicides cannot be used, in more efficient weed control, higher yields and

better use of humans and other resources?”

Fryer says that the answer to each question is yes and great emphasis must be given to weed management as opposed to weed control. Management will force practitioners to redefine their practice. Words and the definitions we create from them are powerful determinants of how we act and what we propose to do. Weed management, Fryer suggests, will help us move away from the “empirical and often uninformed application of physical or chemical techniques to control weeds” toward “the rational deployment” of all available technology to provide systematic management of weed problems in all situations.

Among several excellent examples of integration of techniques, Fryer (31) cites work by Cussans (25) who calculated that if annual herbicide use in continuous spring barley gave an 80% reduction of viable wild oats (*Avena* sp.) seed, the soil population would continue to rise if farmers tine-cultivated soon after barley harvest. If tine-cultivation was omitted and plowing delayed until December, a slow decline in the soil seed bank occurred and the problem diminished. That is weed management and represents a desirable direction for all pest control programs. The direction means weed scientists have to become better ecologists, better observers of their environment, and better managers. They first must use their Promethean power to prevent weed problems and continue to develop and refine control techniques and apply them when necessary, while being ever watchful of Pandora’s problems.

“I must prefer the informed to the convinced, the demonstrated to the revealed, the observed to the imagined, the probable to the impossible, the unalterable fact to the evanescent wish, the reasoned conclusion--however offensive--to the unquestioned assumption--however pleasing.” (8)

As in so many confusing areas of modern life, those affected by the pesticide debate yearn for objective truth that settles issues. Many think they have found it and are willing to describe it for the rest of us.



It often becomes evident that those who are sure they have objective, publicly verifiable, universal truths probably don't and, moreover, they may not understand the question. This essay is not a presentation of objective truth as many will immediately see. It makes suggestions on the controversial and complex issues surrounding pesticides and their use.

Weed scientists are the immediate audience, but the method and message are applicable to a wider agricultural audience. The message is not intended to demean the great accomplishments of weed science. One does not wish to become a tolerated, but acknowledged, heretic within weed science by appearing to abandon what has been accomplished and those who have accomplished it. If heresy is my crime and burning at the intellectual stake my punishment, my final plea is that we continue to think about future directions for weed science as I go up in smoke.



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